ISSN 0098-0196

35th Annual Conference Report on Cotton-Insect Research and Control

January 4–5, 1982
Las Vegas, Nevada

U.S. Department of Agriculture
Agricultural Research Service

RESEARCH--THE BASIS OF PROGRESS

Cotton-insect research contributes to more efficient cotton production by reducing production costs and increasing profits. A continuing research program is essential if a favorable position is to be maintained in the battle with cotton pests. The ability of pests to develop resistance to highly effective insecticides emphasizes the need for a program of basic and applied research. New concepts and methods of control can come only through research.

Basic or fundamental research on the bionomics, physiology, biochemistry, and behavior of insects; on the chemistry of insecticides; and on the physiology of the cotton plant is essential to the development of new concepts of cotton-insect control. This research is essential before major breakthroughs can be achieved in developing insect-resistant cotton varieties, selective insecticides, and new concepts of control; in discovering effective attractants; and in making maximum use of biological control.

Future research output depends on the availability of highly trained personnel working in an atmosphere favorable to productive research. Promising high school and college students should be encouraged to enter the field of professional entomology as teachers, research scientists, extension and survey entomologists, and pest management consultants.

COOPERATIVE EXTENSION--PROGRESS THROUGH EDUCATION

The Cooperative Extension Service in each State bridges the gap between the researcher and the grower by making the most recent research results available for practical use at the farm level. The goal of Cooperative Extension Service entomologists, as well as of research entomologists, is to make cotton production more efficient by reducing production costs and increasing profits through better and more economical insect control. Cotton-insect research is of value only when its findings are used by cotton growers.

The first step in bridging the gap is the joint development of cotton-insect control recommendations which are published as "Guides for Controlling Cotton Insects" by the Cooperative Extension Service in each cotton-producing State. Entomologists and county agents of the Cooperative Extension Service then disseminate this information through farm magazines, newspapers, radio, television, and other educational aids.

Entomologists in the Cooperative Extension Service must have more than a thorough knowledge of cotton insects and their control. They must know how to present this information in a form that will be readily accepted and used by growers. Young people with such aptitude should be encouraged to enter this phase of professional entomology.

AGRICULTURAL CONSULTANTS--IMPLEMENTATION OF PROGRESS THROUGH SERVICE

The many factors involved in integrated pest management are implemented at the field level. Proper decision making for managing cotton insect pests is dependent on high levels of technical knowledge. Professional, qualified, licensed consultants provide expertise in developing necessary field information through a systematic monitoring program. The information is used in applying the most appropriate combination of practices based on research and extension recommendations for each field of cotton.

THIRTY-FIFTH ANNUAL CONFERENCE REPORT ON COTTON-INSECT RESEARCH AND CONTROL

January 4-5, 1982
Las Vegas, Nevada

Sponsored by

Agricultural Experiment Stations
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Louisiana, Mississippi, Missouri, New Mexico,
North Carolina, Oklahoma, South Carolina,
Tennessee, and Texas

and the
Agricultural Research Service
and
Animal and Plant Health Inspection Service
of the
U. S. Department of Agriculture
and the
National Cotton Council of America

Issued February 1982

This publication contains the results of research only. Mention of pesticides does not constitute a recommendation for use, nor does it imply that the pesticides are registered under the Federal Insecticide, Fungicide, and Rodenticide Act as amended. The use of trade names in this publication does not constitute a guarantee, warranty, or endorsement of the products by the U.S. Department of Agriculture.

This publication is available from the Boll Weevil Research Laboratory, P. O. Box 5367, Mississippi State, Miss. 39762.

On June 17, 1981, the Secretary of Agriculture abolished the Science and Education Administration, formerly the publisher of this series, and reestablished the four agencies (Agricultural Research Service, Cooperative State Research Service, Extension Service, and National Agricultural Library) out of which SEA had been organized in 1978. This series will continue under the imprint of the Agricultural Research Service (Southern Region).

Annual Conference Report on Cotton-Insect Research and Control, 35th, January 4-5, Las Vegas, Nevada. Issued February 1982.

Published by Agricultural Research Service (Southern Region), U. S. Department of Agriculture, P. O. Box 53326, New Orleans, La. 70153, from camera-ready copy supplied by the conference.

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PREFACE

This Conference Report is available to anyone interested in cotton production. It may be duplicated in whole or in part, but it should not be used for advertising purposes. No less than a complete section relating to one material or insect, together with any supplemental statements, should be copied.

In utilizing the information presented in this report, individuals should recognize their responsibility with regard to the impact of pesticides on man and on his environment. Wherever possible, control measures consistent with good cotton-insect control and protection of the environment should be used. Control techniques other than insecticidal should be developed for use in the overall program.

Most of the reports of the committees and study groups that were appointed to review and evaluate the status of persistent pesticides recommended that provisions be made for an orderly reduction in the use of persistent pesticides. In response to these recommendations certain registered-use patterns have been canceled. These cancellations mean that farmers and other users often must exercise greater care and caution when protecting their crops with substitute insecticides. Some of these substitutes are far more hazardous to humans than the previously registered pesticides because of their much higher acute toxicity. Pesticide registrations and recommendations are under constant review and are subject to change as warranted. It is the responsibility of all who recommend and use pesticides to be aware of the current status of pesticides and to be guided by it in recommending or using pesticides.

All pesticides are regulated by the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) as amended October 21, 1972, November 28, 1975, and September 30, 1978. The reader is encouraged to contact the nearest regional office of the Environmental Protection Agency for information and details on the provisions and regulations of FIFRA as amended.

CONFERENCE HIGHLIGHTS

Most cotton-producing states reported an increase in insect activity, especially concerning the boll weevil, in 1981.

Trap catches in Fayette and Madison Counties in Tennessee indicated that the boll weevil population had increased over the past year. Boll weevil populations in the delta and hill areas of Mississippi were considered to be higher than in any other year during the past 6 years. In South Carolina, the population was greater than in the past 4 years and caused severe damage in many cases. Control measures were needed across the boll weevil belt, including northwest Florida.

Bollworm and tobacco budworm infestations ranged from light to moderate in most areas. In South Carolina, infestations were similar to 1980 and required control measures in all fields. In several States, the use of vegetable oils in spray applications gave good to excellent control with the pyrethroids.

Thrips infestations in presquaring cotton were heavy and widespread in South Carolina. Infestations were generally light over most of the other States.

Cotton aphid infestations were extremely heavy in southwestern Oklahoma, and control measures were needed. Methyl parathion failed to control cotton aphids in many fields in Louisiana.

Fall armyworms reached economic infestation levels for the first time in Louisiana in 1981, where moths deposited eggs directly on the cotton leaves.

The European corn borer was found in isolated fields in Escambia County, Fla., near the Alabama line. These insects were found boring into the upper third of cotton stems and in the base of bolls.

Whiteflies were an occasional pest in several States, but no special concern or lack of control was reported.

Improvements in rearing boll weevils were accomplished by using a new type of pneumatically operated valve actuator that was installed and tested on one of the pellet making machines. The units performed satisfactorily and should require less maintenance and provide a longer life than the replaced actuators. A tiny dispenser was developed for placing the empty diet trays on the conveyor for filling with diet. The unit eliminated placing the trays on the conveyor by hand.

The importance of temperature and relative humidity during ovipositioning was determined. Ovipositioning adult boll weevils were exposed to four relative humidities at two air temperatures, and the effects on egg production and hatch were measured. Egg production and hatch were lower at the higher (55 and 65 percent) than at the lower (35 and 45 percent) relative humidities at both (28.9° and 31.1°C) temperatures tested.

The presently used method of boll weevil sterilization consists of feeding adults on 100 p/m of diflubenzuron for 5 days and then giving 10,000 rads of irradiation on the 6th day. Various types of nutrition, sterility, and quality-control research were conducted on boll weevils sterilized in this manner.

Pheromone production from individual male boll weevils was quantitated for 24-hour periods using a newly developed high-pressure liquid chromatographic method. Adults held in darkness produced no pheromone but, when transferred to a long photophase, began pheromone production immediately.

The site of pheromone synthesis within the male was determined to be localized within the fat body of the adult. When fat bodies were further incubated in saline with ATP, increased pheromone production was monitored.

The mineral composition of eggs, larvae, adults, and boll weevil diets of native and laboratory populations is being completed. Also, the effects of diflubenzuron and irradiation on the mineral composition is being studied.

In sterility studies, the use of a vacuum during the irradiation of adults has had a positive influence on increasing the longivity of adults following treatment.

A new bioassay apparatus was developed to compare responsiveness of sterile and normal boll weevils, and sterilized boll weevils were found to be about 60 percent as attractive when compared with normals for the first 5 days after treatment.

It was also determined that when diflubenzuron was fed to boll weevils, cuticle hardening was impaired and mating ability was reduced. A new material was tested to replace diflubenzuron. In laboratory studies, male boll weevils that had been fed the ecdysteroid β-SEA-28 for 5 days before irradiation were 99.5 percent sterile and had a mating capability that was more than twice that of males fed diflubenzuron before irradiation. These males also lived slightly longer than the diflubenzuron-fed males. Female sterility was complete. Boll weevils fed the ecdysteroid, followed by fumigation with bisazin, were also more competitive than diflubenzuron-fed boll weevils.

In tests in isolated field plots, the males fed β-SEA-28 were 3.5 times more competitive against untreated males than were diflubenzuron-fed males. It appears that we now have a method of sterilizing the boll weevil that is superior to the one used in the Boll Weevil Eradication Trial conducted in North Carolina in 1979.

In 1981, improvements were made on the motorbike dispersal unit that was tested in 1980. A wide 12-inch-tire motorbike was compared to a narrow 2.75-inch-tire motorbike for conveying the dispersal system in the fields. A unit was developed that could disperse boll weevils without their being chilled or anesthetized with a gas. The wide-tire bike handled much easier in the cultivated fields. The mortality of boll weevils dispersed by the machine was comparable to control groups.

In field tests composing simulated uniform and clumped release of sterilized weevils in south Mississippi and Arkansas, reductions in egg hatch, highest percentage of punctured squares, and average number of captured weevils were noted and markedly so, in the two tests, respectively.

In disruption studies, the use of large quantities of the boll weevil pheromone grandlure in isolated field plots resulted in significantly lower population growth, as measured by percentage of punctured squares, in the treated plots than in the untreated plots.

The field technique for applying first-instar Heliothis virescens larvae to cotton plants to develop uniform infestations was utilized again in 1981. We did not experience any problems in the application of the larvae or in the techniques associated with it. Uniform infestations were developed in the field, and damage sufficient to separate breeding lines for different levels of resistance was obtained.

In a recent survey of coastal Tamaulipas, Mexico, boll weevil infested wild cotton was found at a site where similar colonies had existed in 1939. This is approximately 150 miles south of Brownsville, Tex.

Four existing translocated pink bollworm strains, developed through crossing procedures designed to produce homozygosity, carried recessive lethal factors associated with the translocation, which made it impossible to maintain the homozygous strains. Thus, these translocated strains must be maintained as heterozygotes. Crosses plus selection designed to eliminate such recessive lethal factors are planned for the coming year. Balanced sex-linked lethal stocks have not yet been recovered from irradiation tests of previous lethal-carrying strains.

Under laboratory conditions, in the first generation of overflooding the native pink bollworm population with the nondiapause strain, the control native population did not reproduce, thus no comparisons could be made to indicate the success of the test; however, nondiapaused insects constituted about 70 percent of the experimental populations. New tests were initiated after it was found that diapause response of the nonselected WCRL strain was greater than 97 percent, thus making it possible to guarantee reproduction of the control populations. In the first generation of these new tests, a differential response of reciprocal crosses was obtained, thus indicating at least partial sex linkage of the nondiapause character.

In a successful laboratory cage test of partially sterilized sooty pink bollworms, the effect of continuous release of treated insects vs. a single release was examined. With a treatment of 5,000 rads, the insects did not successfully control the population under either release scheme, but at a treatment of 10,000 rads and continuous release, each generation was significantly better at control than a single release per season. The latter treatment gave better control under either release scheme. The presence of the sooty marker allowed close observation of the sterile insects.

Preliminary studies of the early season distribution and movement of pink bollworms were made using mark and recapture techniques. Males moved freely between desert, sugar beet, alfalfa, and cotton habitats during April and May. About 80 percent of female moths captured in light traps during this period were mated, regardless of the habitat in which they were captured. Virgin females placed in minimating stations in desert and cotton habitats were equally mated in one night exposure (about 50 percent mated).

No significant difference was found in the response of pink bollworm males to the isomer ratios in gossyplure-treated or untreated atmospheres. Thirty-six percent of males captured in treated or untreated fields were caught in traps containing the 1:1 ratio. There was a 90 percent reduction in the number of males trapped in treated fields.

Volatiles from six species of plants in two families (Malvaceae and Leguminaceae) were analyzed by gas chromatography - mass spectrometry. No generalizations could be made as to which compounds act as attractants of pink bollworms to cotton. Three compounds were found in cotton but not in alternate hosts: caryophyllene, pinene, and limonene.

Nine new sprayable formulations of gossyplure were evaluated for attractancy and disruption control capabilities. Two of the formulations provided as good as or better disruption of mating than twice the recommended rate of Conrel fiber. One bait formulation showed considerably better attractancy and longevity than baits formulated in a standard rubber septum.

Pink bollworm male moths were captured every month of the year in Sea Island cotton plots on St. Croix, U.S. Virgin Islands. The numbers ranged from about 0.2 to 1.5 males per trap per night. Highest numbers were caught from November through April, decreasing thereafter through October. Higher

numbers of male moths were caught in commercial cotton and in okra plots. Numbers caught ranged from about 1 to 15 and 5 to 31 male moths per trap per night in cotton and okra plots, respectively. Peak catches were recorded between 2 and 4 a.m., with reduced male activity, as measured by the traps, occurring between the hours of midnight and 2 a.m. and 4 and 6 a.m.

The numbers of pink bollworm larvae per boll in commercial cottons on St. Croix ranged from 0.2 to 2.2. Numbers of larvae per boll in Sea Island cotton were highest in November (0.47 per boll) and ranged from zero to 0.47 per boll through May, when the last available bolls for sampling were found.

Okra pods were also heavily infested with pink bollworm larvae; infestations ranged from 0.3 to 8.1 per pod.

Gossyplure (1:1 mixture of Z,Z- and Z,E-isomers of 7,11-hexadecadien-1-ol acetate) in plastic laminated formulations of 35 or 10 g of active ingredient per 2.54 cm^2 applied at rates of 2.96 to 4.94 of active ingredient per hectare to cottonfields reduced male pink bollworm moth catches in pheromone-baited traps an average of 80 to 86 percent (range, 40 to 99 percent) and clipped-wing female mating in mating stations 90 to 92 percent (range, 52 to 100 percent) for 13 to 16 nights after application.

Coccinella septempunctata beetles recovered from the New Jersey Meadowlands had a development rate similar to that of a European strain. Studies were conducted to develop methods for holding eggs and young larvae of *Chrysopa carnea* at low temperatures to delay hatching and growth so they could be stored for use in spring aphid control in cold frames. High mortality resulted from storage under different temperature and moisture conditions.

Pink bollworm male moth activity, as measured by gossyplure-baited Delta traps, was not significantly different in nectariless or nectaried cotton nor in the 2- or 40-inch row-spacing plots. Larval infestations in bolls reached about 14 percent during July 23-28, and the first insecticide application was applied. Treatments for the remainder of the season effectively controlled pink bollworms. There were no significant differences between the number of larvae-per-boll samples from narrow row (20-inch) or standard row (40-inch) plots nor from boll samples from nectaried or nectariless cottons.

Numbers of *Lygus* spp. were high in June but decreased in July, and significantly more were found in nectaried cotton than in nectariless cotton. There were no significant differences in the numbers of *Lygus* spp. found in narrow or standard row plots of either type of cotton.

Dicamba plus chlorflurenol had no significant effect on the numbers of green bolls until about 29 to 33 days after treatment. Thereafter, the numbers of green bolls in the treated plots were significantly less than in the untreated check plots. On November 10, the number of green bolls and diapause pink bollworm larvae found in the treated plots were reduced 97 percent as compared to those found in the check plots. Fewer green bolls were found in Pennwalt TD-1123 treated plots about 21 to 29 days after treatment, and, on November 10, the numbers of green bolls and diapause larvae were reduced about 90 percent as compared to those found in the check plots. None of the plant growth regulator treatments affected the numbers of pink bollworm larvae in bolls.

Diapaused pink bollworm larvae in bolls were buried under pyramid emergence cages on February 1, March 6, or left on the surface after February 1, 1980. Also, cutout larvae (in free cocoons in tissue paper) that were collected at different times during the fall of 1979 were buried on February 6. Supplemental irrigation at monthly intervals was applied to half of the cages of

each treatment. There were no apparent differences in the emergence patterns among any of the treatments. An average of 15.6 percent of the cutout larvae emerged when not irrigated, and the supplemental irrigation reduced the survival by 6.7 percent. Of the larvae remaining in bolls, survival was greatest among those left on the soil surface, and the least among those buried on February 1. In all cases, the supplemental irrigation reduced the survival about 50 percent.

'AET 5', a pink bollworm-resistant cotton stock, and 24-8 nectariless were grown along with their F_1, F_2, and backcross hybrids. Only additive genetic effects were significant; heritability of seed damage was 24 percent.

'AET 5' was backcrossed to BC_2 and BC_3 plants selected for various combinations of the visible pink bollworm resistance characters: nectariless, smoothleaf, okraleaf, super okraleaf, and early maturity. The objective was to incorporate these visible characters into 'AET 5' background to study their cumulative effects on pink bollworm resistance.

In the greenhouse, the number of pink bollworm entrance holes per boll were lower in 'AET 5' than in 'DPL 61', both when pink bollworm moths had a choice of plants upon which to oviposit and when they did not. In a subsequent free-choice test, moths laid more eggs per boll on 'AET 5' the first week but more on 'DPL 61' the second week. The mean difference was not significant. The distribution of eggs on different parts of the plant was about the same for both cottons, with about one-third to one-half of the eggs being in leaf and limb axils and one-third or more on bolls and with lower percentages on other parts of the plant. An unexpected phenomenon was that many eggs were laid at the base of the stems and in the soil (not included in the eggs-per-plant totals because we assume at present that larvae hatching from these eggs would not reach squares or bolls). In the field late in the season, moths laid fewer eggs on 'AET 5' than on 'DPL 61' but many more on 'Pima S-5'. Distribution of eggs on 'AET 5' and 'DPL 61' was similar to that observed in the greenhouse. On 'Pima S-5', moths laid 75 percent or more of their eggs on the bolls.

"Horseshoe" stage larvae of the cotton leafperforator were counted weekly for 8 weeks on leaves of 13 test cottons and a commercial check. Leaf hairs were also counted. Seven test cottons had fewer "horseshoe" larvae per gram of leaf tissue than the check, 'DPL 61'. These included four cottons from the high-tannin, smoothleaf HT35 family.

Cottons carrying all combinations of okraleaf, frego bract, and smoothleaf were tested for seed damage by pink bollworm for the third year. Combined analysis of the data showed that cottons carrying okraleaf had significantly less seed damage than those with normal leaves. Smoothleaf cottons had more damage than hirsute cottons, but frego-bract strains did not differ in seed damage from normal bract strains.

'AET 5', 'DPL 61', and 'Pima S-5' were evaluated for seed damage by pink bollworm and agronomic properties in unsprayed plots and in plots sprayed with carbaryl. Seed damage was significantly higher in the unsprayed plots. Mean seed damage was lower in 'AET 5' than in 'DPL 61' or 'Pima S-5' but was similar in the latter two cultivars. The economic level of seed damage (i.e., level at which a measurable yield loss occurred) was about 10 percent in 'DPL 61' and 'AET 5' but about 18 percent in 'Pima S-5.'

Estimates of the reduction in 1981 cotton yields resulting from insect damage and the cost of control (materials plus application) are given in table 1.

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Table 1.--Estimated reduction in 1981 cotton yields resulting from insect damage[1]

Loss attributable to	State								
	Ala.	Ariz.	Ark.	Calif.	Fla.	Ga.	La.	Miss.	Mo.
Boll weevil:									
Percent---------	5.5	0.13	2.75	NA	6.0	3.2	3.9	2.7	0
Bales-----------	23.0	2.0	17.2	NA	0.9	5.0	29.0	43.0	0
Bollworm-tobacco budworm:									
Percent---------	4.5	1.5	1.5	0	7.0	5.1	4.9	2.6	5.0
Bales-----------	18.8	23.3	9.4	0	1.1	7.9	36.8	41.5	8.1
Cotton fleahopper:									
Percent---------	0	0.02	0.05	0	0	0	0.3	0.05	0.30
Bales-----------	0	0.31	0.31	0	0	0	2.3	0.70	0.4
Lygus spp. and other plant bugs:									
Percent---------	1.3	1.3	0.75	1.6	0.3	1.1	0.4	0.2	1.5
Bales-----------	5.4	20.0	4.7	55.0	0.05	1.7	3.0	3.1	2.4
Cotton leaf perforator:									
Percent---------	NA	0.9	NA	0	NA	NA	NA	NA	NA
Bales-----------	NA	13.5	NA	0	NA	NA	NA	NA	NA
Pink bollworm:									
Percent---------	NA	2.9	NA	0	NA	NA	NA	NA	NA
Bales-----------	NA	45.0	NA	0	NA	NA	NA	NA	NA
Spider mite:									
Percent---------	0.6	0.3	0.2	4.0	0.2	0.1	0.6	0.1	0.5
Bales-----------	2.5	4.3	1.3	124.0	0.03	0.2	4.5	1.9	0.8
Thrips:									
Percent---------	1.7	0	1.0	0	0.2	0.1	0.5	0.2	2.0
Bales-----------	7.0	0	6.3	0	0.03	0.2	3.8	2.7	3.2
Others:									
Percent---------	[4,10,12] 0.7	[5,6,9] 1.1	0	0	[4,9] 0.6	[4,5] 0.5	[4,8,10] 1.1	[4,5,9,11] 0.3	[7] 1.5
Bales-----------	3.0	17.5	0	0	0.09	0.8	8.3	5.0	2.4
Total percent loss--	14.3	8.1	6.3	5.2	14.3	10.1	11.7	6.2	10.8
Total bale loss-----	59.6	126.0	39.1	179.0	2.2	15.7	84.8	98.0	17.2
Control cost/acre($)[13]	41.70	69.00	26.40	21.70	135.00	72.00	49.50	33.40	7.00
Yield in bales[14] ----	418	1,550	625	3,450	15	155	750	1,570	162

See footnotes at end of table.

Table 1.--Estimated reduction in 1981 cotton yields resulting from insect damage--Continued[1]

Loss attributable to	State							No. bales lost, all States[2]	Pct. loss, avg. all States[3]
	N. Mex.	N.C.	Okla.	S.C.	Tenn.	Tex.	Va.		
Boll weevil:									
Percent---------	NA	2.0	NA	4.1	1.0	1.2	0		1.29
Bales-----------	NA	1.8	NA	6.6	3.1	70.1	0	200.83	
Bollworm-tobacco budworm:									
Percent---------	9.0	13.0	8.0	3.1	5.0	1.8	3.0		2.08
Bales-----------	10.0	11.3	33.0	5.0	16.0	103.0	0.01	323.71	
Cotton fleahopper:									
Percent---------	3.0	0	0.5	0	0	1.1	0		0.46
Bales-----------	3.3	0	2.1	0	0	63.0	0	71.03	
Lygus spp. and other plant bugs:									
Percent---------	6.0	0	0	0.2	3.0	0.17	0		0.78
Bales-----------	6.6	0	0	0.3	9.3	9.70	0	121.56	
Cotton leaf perforator:									
Percent---------	0.1	NA	0	NA	NA	NA	NA		0.09
Bales-----------	0.1	NA	0	NA	NA	NA	NA	13.6	
Pink bollworm:									
Percent---------	2.0	NA	0	NA	NA	0.03	NA		0.31
Bales-----------	2.2	NA	0	NA	NA	1.7	NA	49.02	
Spider mite:									
Percent---------	0.1	0.5	0.1	0.1	3.0	0.01	0		0.97
Bales-----------	0.1	0.5	0.4	0.1	9.0	0.5	0	150.53	
Thrips:									
Percent---------	3.0	0.1	0.5	0.5	0.1	0.05	0		0.21
Bales-----------	3.3	0.05	2.1	0.8	0.2	2.6	0	31.98	
Others:									
Percent---------	0	[7]4.0	[10,12]0.6	[4,7]0.8	[10]0.2	[9]0.2	0		0.55
Bales-----------	0	3.6	2.3	1.2	0.6	41.0	0	85.51	
Total percent loss--	23.1	19.1	9.7	8.7	12.3	5.0	3.0	-----	----
Total bale loss-----	25.4	17.2	39.6	14.0	38.1	286.1	0.01	-----	----
Control cost/acre($)[13]	14.00	7.80	42.50	90.00	3.50	25.00	24.00	-----	----
Yield in bales[14] ----	110	90	410	160	310	5,700	0.0450	-----	----

[1]All bale figures in table x 1,000. Estimated by research, extension and others based on Statistical Reporting Service December Report. NA, not applicable.

[2]No. bales lost--1,040 to nearest 10^4.

[3]Total pct loss--6.74.

[4]Fall armyworm (*Spodoptera frugiperda* (J. E. Smith)). [5]Beet armyworm (*Spodoptera exigua* (Hübner)).

[6]Stink bugs (*Euschistus* spp.). [7]European corn borer (*Ostrinia nubilalis* (Hübner)). [8]Yellowstriped armyworm (*Spodoptera ornithogalli* (Guenee)). [9]Grasshoppers (*Schistocerca americana* (Dury)).

[10]Cotton aphid (*Aphis gossypii* (Glover)). [11]Cutworms (*Agrotis* spp.); (*Feltia subterranea* (F)).

[12]Whitefly (*Trialeurodes abutilonea* (Haldeman)). [13]Average control cost for all States--$41.41.

[14]Total yield for all States--15,475.

INTRODUCTION

This report of the 35th Annual Conference of State and Federal workers is concerned with cotton-insect research and control. Research and extension entomologists and associated technical workers from 15 cotton-growing States, the United States Department of Agriculture, National Cotton Council of America, Cotton Incorporated, Plains Cotton Growers Inc., the Environmental Protection Agency (EPA), National Agricultural Chemical Association, and industry met to review the research and experiences of the previous year and to formulate guiding statements for control recommendations in 1982. The chief purpose of the Conference is to enable the exchange of information that may be useful in planning further research, survey, and extension work, and to make the results of research available to others.

The report presents information of value to (1) industry in planning production programs, (2) State and Federal research workers in planning research programs, (3) extension entomologists in bringing to the attention of growers and other interested groups the control recommendations for their States, (4) teachers of entomology in the various colleges and universities, and (5) to consulting entomologists. It is also widely used in foreign countries in connection with the development of cotton-insect control programs.

Agreement on overall recommendations may be expected; however, complete standardization throughout the Cotton Belt is not possible. Details of recommendations will vary with the region or locality. Cottongrowers in the respective States should follow the recommendations contained in the State "Guides for Controlling Cotton Insects" and the advice of qualified entomologists familiar with local problems.

Determining the species and abundance of various insects and the specific injuries inflicted upon the cotton plant is important in insect control. Knowledge of the life history and habits of the insects, the growth and fruiting characteristics of cotton plants, and the environmental relationships that exist between the plants and insects yields additional information basic to an evaluation of the economic insect situation involved. Each control measure used should be a part of an integrated control program, utilizing to the fullest extent wherever possible cultural, physical, mechanical, biological, legal, and natural controls. However, when the level of infestation of an insect or group of insects approaches the economic threshold, chemical control measures should be applied to prevent damage to the cotton crop. Insecticides, dosages, formulations, and timing schedules should be selected to solve existing problems without creating new ones.

In making recommendations for the use of insecticides, entomologists should recognize their responsibility with regard to hazards to the public. (See "Insecticides and Miticides.") The insecticide industry has a great responsibility to the cottongrower in making available adequate supplies of recommended materials that are properly formulated. Sales programs should be based on State or area recommendations.

Various "remedies" and devices, such as concoctions of unknown makeup, bug-catching machines, light traps, and other mechanical or electrical contrivances for controlling insects, have been put on the market through the years. Although some had slight value, most were less effective and more expensive than widely tested standard methods. Cottongrowers are urged to follow approved recommendations known to be of sound value.

Research results on cotton-insect control obtained by the United States Department of Agriculture and the State experiment stations are extended to the cotton industry by the Cooperative Extension Service in each State. It is the responsibility of each individual farm operator to make decisions concerning the control of cotton insects. He may do this himself or he may delegate the job to someone else. (See "Determining the Need for Chemical Control.")

PROGRESS IN INSECT REARING

Research on cotton insects was hampered for many years because of difficulties encountered in rearing them in the laboratory. It was difficult, as well as expensive, to rear insects in needed numbers on their hosts. Major breakthroughs in research could only come through the ability to mass-rear the various insects on artificial diets. Progress in insect rearing enhanced research on detection, migration, and insecticide evaluation as well as on the sterile-male release technique for control of certain insects.

Pink bollworm.--The first phytophagous insect to be reared on an artificial diet was the pink bollworm, in the early 1950's at USDA's Cotton Insects Research Laboratory, College Station, Texas. The artificial diet developed for this insect has served as the basic diet for many phytophagous insects now being mass-reared in the laboratory. The pink bollworm is mass-reared at the rate of 13 million to 17 million per week in the Pink Bollworm Rearing Facility, Animal and Plant Health Inspection Service (APHIS) at Phoenix, Arizona. The insects are made sexually sterile and are released in the San Joaquin Valley of California at selected locations where migrant moths had been captured. The releases apparently prevented the establishment of infestations by occasional migrants from the Imperial and Coachella Valleys until 1977, when a few larvae were found in cotton bolls. The sterile insect releases were continued in 1978, 1979, 1980, and 1981. No additional larval infestations were found until 1980. In the off-season, sterile-moth releases were made for several years to wild cotton in the southern tip of Florida for suppression of pink bollworm populations on that host. For many years populations were suppressed by manual destruction of wild cotton plants, which was a costly and almost impossible task. The new technique was made possible through the development of mass-rearing procedures for the insect.

Boll weevil.--In the early 1960's boll weevils were reared on artificial diets at the USDA Cotton Insects Research Laboratory in College Station, Tex. Improvements in rearing were made at that laboratory and at the Baton Rouge, La., and Florence, S.C., laboratories. Progress in mass rearing the insect was made with the establishment of USDA's Boll Weevil Research Laboratory on the Mississippi State University campus in 1961. After it became apparent that the insect could be reared in sufficient numbers, it was deemed that a Pilot Boll Weevil Eradication Experiment should be conducted to determine whether it was technologically and operationally feasible to eradicate the boll weevil. With an appropriation of more than $0.5 million from the Mississippi Legislature, the Robert T. Gast Rearing Laboratory was built on the Mississippi State University campus. Problems with the rearing facility, as well as with rearing procedures, prevented production of the numbers of

insects needed for sterile-male releases; however, the facility made a significant contribution to the success of the experiment. The rearing procedure has been automated, the vigor of weevils increased, and sterilization procedures improved. The facility has provided needed numbers for the Boll Weevil Eradication Trial initiated in 1978 and completed in 1980 in North Carolina and Virginia. The Gast Rearing Laboratory or a larger rearing facility is expected to play an integral part if eradication of the boll weevil from the United States is undertaken.

Bollworm.--Diets and techniques for rearing the bollworm also were developed at the USDA laboratory in College Station, Tex. Though small cultures were reared at several laboratories, the major thrust in mass rearing was done at the USDA Southern Grain Insects Laboratory at Tifton, Ga. A prototype machine for mass rearing the insect was developed at this laboratory. Moths were reared for several years for the identification of the sex pheromone emitted by the female. The sex pheromone was isolated, purified, identified, and synthesized in 1978.

Tobacco budworm.--Techniques for mass rearing the tobacco budworm were developed at the USDA Cotton Insects Research Laboratory in Brownsville, Tex., in the late 1960's and early 1970's. Production was stabilized at about 60,000 pupae per day. Pupae were furnished from this laboratory for the sterile-male release study conducted on St. Croix, U.S. Virgin Islands, in the early 1970's. In addition, moths were reared for several years for the identification of the sex pheromone emitted by the female. Chromatographic analysis indicated it to be a multiple component system. The sex pheromone was isolated, purified, identified, and synthesized early in 1974. In the Stoneville Laboratory more than four million backcross (BC) pupae (BCn♀ x *H. virescens*♂) from the intercross (*H. virescens*♂ x *H. subflexa*♀) have been produced in the last 3 years. Insects are also produced for use in public and private research.

Lygus bugs.--*Lygus hesperus* and *L. lineolaris* have been reared on artificial diets. A system based on a meridic diet has been used to rear a colony of *L. hesperus* for over 10 generations. A large packet with a parafilm membrane on one side and polyethylene backing is being used for rearing large numbers.

Saltmarsh caterpillar.--The saltmarsh caterpillar, *Estigmene acrea* (Drury) has been reared on the wheat germ diet at the USDA laboratory in College Station and has been mass-reared at USDA's Biological Cotton Insect Control Laboratory in Tucson, Ariz.

Beneficial insects.--The green lacewing has been reared in the laboratory on an artificial diet, and some progress has been made in mass rearing it on this diet. Some progress has also been made in rearing *Campoletis perdistinctus* and *Microplitis sonorensis*, parasites of *Heliothis* spp., on artificial diets. Two diets have been developed that yielded fertile *Geocoris* spp. adults, although yields were low.

COTTON-INSECT CONTROL METHODS

Entomologists have made considerable progress in developing methods for controlling cotton insects. An insect pest management system was developed in Arkansas in the 1930's and 1940's based on scouting, spot dusting and early maturity of the cotton crop. In the late 1940's and 1950's a system of early-season insect control on a community-wide basis was developed in Texas. In the 1970's a Heliothis spp. population management system on a community-wide basis was developed in Arkansas. In Texas, the development and use of short-season rapidly fruiting and determinate genotypes along with uniform planting, area-wide post harvest stalk destruction and field scouting has substantially reduced the insect problems. It is extremely important that various insect control practices be integrated into a system such as Integrated Pest Management. However, it must go beyond the control of various pests such as insects, diseases, nematodes and weeds but must encompass the best production practices for all crops grown within an ecosystem.

Cultural Practices

Certain cultural practices reduce insect problems and may give adequate control without the use of insecticides. Several of these practices can be followed by every cottongrower whereas others are applicable only to certain areas and conditions. Growers following these practices should continue to make careful observations for insects and apply insecticides only when needed.

Early stalk destruction.--The boll weevil resistance problem emphasizes the urgent need for early destruction of cotton stalks. The destruction or killing of cotton plants as early as possible before the first killing frost prevents population buildup and reduces the overwintering population. The earlier the weevil population is deprived of its food supply the more effective this measure becomes. Early stalk destruction, especially over communitywide or countywide areas, has greatly reduced the boll weevil problem the following season, especially in the southern part of the Cotton Belt.

Early stalk destruction and burial of infested debris are generally the most important practices in pink bollworm control. Modern shredders facilitate early stalk destruction and complete plowing under of crop residues. The shredding operation also kills a high percentage of pink bollworms left in the field after harvest. The flail shredder is recommended over the horizontal rotary shredder for pink bollworm control. Plowing under crop residue as deeply as possible after the stalks are cut will further reduce survival of the pink bollworm. The use of these machines should be encouraged to control both the boll weevil and pink bollworm. Early stalk destruction can also reduce the potential number of overwintering bollworms and tobacco budworms.

Stub, volunteer, or abandoned cotton.--Stub, volunteer, and abandoned cotton contributes to insect problems because the stalks and undisturbed soil provide a place for insects to live through the winter. This is especially true for the cotton leafperforator, pink bollworm, and boll weevil. Volunteer cotton is also the principal winter host for the leaf crumple virus of cotton in the southwestern desert areas and for its whitefly vector. All cotton plants should be destroyed soon after harvest.

Planting.--Uniform planting of all cotton within a given area during a short period of time is desirable. A wide range in planting dates extends the fruiting season, which tends to increase populations of the boll weevil, pink bollworm, and possibly other insects. Planting during the earliest optimum period for an area also makes early stalk destruction possible.

Stands.--With the elimination of chopping by hand, planting to a stand has become necessary. Excessively thick stands are attractive to *Heliothis* spp. and plant bugs and should be avoided.

Row spacing.--Cotton is usually planted in rows 38 or 40 inches apart. Skip-row planting has been popular because it permitted planting more acres of allotment with no decrease in solid acre yields. Insects and spider mites that feed on weeds allowed to grow in these strips may move into the cotton when such weeds are destroyed by cultivation. The skip-row practice necessitates modification of ground application equipment. Applications by airplane become more expensive since the entire field must be treated and only a part of it is planted to the crop. Although yields may not be reduced, skip-row planting may delay maturity and increase the period the crop must be protected from insects.

Narrow-row spacing, including drilling with a grain drill or broadcasting, has been researched heavily in recent years. The advantage lies in a short production season, which reduces insect problems. The system has not been generally accepted because (1) heavy demands are placed on moisture and nutrients in a short period of time, and (2) once over harvest by pickers continues to pose problems and stripper harvesters are not adapted to all parts of the Cotton Belt. Such a system requires aerial application of insecticides. Without cultivation, chemical weed control may be inadequate for control of alternate hosts of certain insects and spider mites.

Varieties.--Varieties of cotton that bear prolifically, fruit early, and mature quickly may set a crop before the boll weevil and other insects become numerous enough to require prolonged treatment with insecticides. This is especially true when other cultural control practices are followed. Growers should plant varieties recommended for their particular area. Cotton breeders are working with entomologists to develop varieties resistant to several cotton insects. Nectariless varieties that offer some degree of resistance to plant bugs are commercially available. So called short season or early maturing varieties are grown in Texas.

Soil Improvement.--Fertilization, crop rotation, and green manure crops are good farm practices and should be encouraged. The increased plant growth, which usually results from these practices, may also prove attractive to some pests, necessitating closer attention to their abundance and control. The potential higher yields will give greater returns from the use of insecticides. Overfertilization, especially with nitrogen, may unnecessarily extend the period during which insecticidal protection is necessary. Likewise, undergrowth and delayed maturity may result from nutritional or moisture imbalance, but these factors should not be confused with insect damage.

The fact that a number of insects and spider mites attack legumes and then transfer to cotton should not discourage the use of legumes for soil improvement or crop rotation. Insect pests may be controlled on both crops.

Irrigation.--Irrigation must be used to produce the crop in arid areas and is used to supplement moisture in drouth periods in the rainbelt. Rank growth and a longer fruiting period complicate insect control, and the disadvantages must be balanced against expected yield increase and fiber quality. Judicious use of water must be exercised in producing the crop.

Other host plants of cotton pests.--Cottonfields should be located as far as is practicable from other host plants of cotton insects. Some control measures should be applied to other hosts such as safflower in California to prevent migration to cotton. Thrips breed in onions, potatoes, carrots, legumes, small grains, and some other crops. They later move in great numbers into adjacent or interplanted cotton. Beet armyworms, garden webworms, lygus bugs, stink bugs, variegated cutworms, western yellowstriped armyworms, and other insects may migrate to cotton from alfalfa and other plants. The cotton fleahopper migrates to cotton from horsemint, croton, and other weeds. Spider mites spread to cotton from many weeds and other host plants adjacent to cottonfields.

Overwintering areas.--The boll weevil hibernates in well-drained, protected areas in and near cottonfields. Spider mites overwinter on low-growing plants in or near fields. Pest-breeding weeds along turnrows and fences or around stumps, as well as scattered weeds in cultivated fields, should be eliminated with herbicides or by using cultural or other methods. General burning of ground cover in woods is not recommended. Since ground cover and weeds serve as hibernating sites for many parasites and predators, the detrimental effects on beneficial insects of indiscriminate destruction of weeds by burning and tillage are obvious.

Seed cotton scattered along turnrows, loading areas, and roadsides serves as a source of pink bollworm carryover to the next crop. Care should be taken to see that these areas are cleaned up. To minimize this hazard, trucks, trailers, and other vehicles in which the seed cotton is being hauled to the gin should be covered.

Gin-plant sanitation should be practiced to eliminate hibernating quarters of the boll weevil and pink bollworm. In areas where pink bollworms occur, State quarantine regulations require that gin trash be run through a hammer mill or fan of specified size and speed, composted, or given some other approved treatment.

Quarantine regulations require certification of mechanical cotton pickers and strippers moving from pink-bollworm-infested to noninfested areas.

Insect Attractants

Boll weevil.--In the 1950's an observation was made at USDA's Cotton Insects Research Laboratory, Stoneville, Miss., that the male boll weevil moved very little on the cotton plant, indicating that he might be visited by females. In 1963 field observations made by personnel of USDA's Boll Weevil Research Laboratory at Mississippi State, Miss., indicated that the female boll weevil aggressively sought the male rather than the more usual procedure in insects of the male seeking the female. In laboratory studies at the same location it was determined that the male produces a sex attractant (pheromone) that is attractive to females, and subsequently the pheromone was identified

and synthesized. It was named grandlure and is now commercially available and widely used in migration, survey, and detection procedures. Traps baited first with live male weevils and later with grandlure were developed to capture boll weevils. Grandlure also acts as an aggregant, since both sexes respond to it especially in early- and late-season. Traps baited with grandlure and placed along the edges of cottonfields capture tremendous numbers of overwintered boll weevils.

In the Pilot Boll Weevil Eradication Experiment conducted in south Mississippi and in adjoining areas of Louisiana and Alabama in 1971-73, traps baited with grandlure were installed, two traps per acre, around field edges as one of the suppression measures in the core or eradication area. Trap crops consisting of cotton planted some 2 weeks earlier than that of the grower cotton were baited with grandlure at 100-foot intervals. Plants in the trap crops were treated in-furrow at planting with aldicarb, a highly effective systemic insecticide, and sidedressed with it at early squaring to kill overwintered weevils attracted to them. The trap crops were treated with methyl parathion during periods when the aldicarb treatment was considered ineffective. Very few weevils were found in the grower cotton before it began to fruit. Even after grower cotton began to square, weevils continued to be attracted to the trap crops, as evidenced by the collection of sterile males that had been released in the grower cotton. The development of in-field traps, those that can be used within fields without interfering with cultivation, baited with grandlure has potential as a tool in population suppression or elimination programs.

Alternate strips of cotton, comprising about 10 percent of the acreage, may be baited with grandlure to attract overwintered boll weevils, which can then be killed with insecticides applied to the baited strips. If weevil populations are low, such treatments may prevent injurious infestations in the remainder of the field for the season.

Grandlure was registered by EPA in 1979 for use in managing populations of the boll weevil.

Considerable unsuccessful effort has been expended in developing attractants from cotton plants for use in controlling the boll weevil. Interest in boll weevil attractants from the cotton plant was revived by researchers in the 1960's. Water and chloroform extracts of cotton-plant parts were attractive. A powerful arrestant and feeding stimulant was found in water extracts of all cotton parts and square components tested. A feeding deterrent was found in the calyx of an alternate host, _Hibiscus syriacus_. However, the chemistry of the arrestant and attractant compounds in the cotton plant is so complex that chemists have been unable to identify and synthesize all of them for use in control, suppression, or survey programs.

Pink bollworm.--It was determined in the mid-1960's that the female pink bollworm moth emitted a substance that attracted males. Chemists identified and synthesized the substance and named it propylure. Unfortunately, propylure, though attractive to males in the laboratory, failed to perform in the field. Apparently, something was missing in the synthesized compound. A somewhat structurally related compound was found to attract males. It was named hexalure and was widely used in the West in survey and detection operations. Though not as attractive as the natural pheromone, hexalure was sufficiently attractive to be used to bait traps so that use of live females was obviated. An intensive effort was made by USDA chemists to identify and

synthesize the pheromone, but progress was slow. However, in late 1973 researchers at the University of California, Riverside, identified and synthesized the compound, and USDA chemists verified their findings. It was named gossyplure. It has gained considerable practical application for use in survey, detection, and population suppression programs and is under investigation in large field experiments as a confusant to prevent the male from locating the females. Traps baited with gossyplure are used to time insecticide applications for control of pink bollworms in the Imperial Valley of California. Gossyplure is registered by EPA for managing populations of the pink bollworm.

Tobacco budworm and bollworm.--Females of the tobacco budworm and bollworm produce powerful sex pheromones to lure males of their respective species for mating. Research has continued since 1963 on these pheromones, with the ultimate goal of producing synthetic materials that could be used for population survey and suppression.

The pheromone of the female tobacco budworm, virelure, was identified and synthesized. A crude extract of the pheromone from females had very short activity, and a similar problem has been found with the synthetic material. Recent research developments have enhanced the potency of the pheromone. It is being field-tested as a confusant.

A similar attractant has recently been discovered for the bollworm; it was isolated, identified and synthesized in 1978.

Pheromones of the two species make possible the development of population suppression schemes. Among the methods suggested for use of these materials are eliminating males by trapping or dispensing the attractant on an insecticide-treated substance, luring the males to a substrate treated with chemosterilants, or saturating an environment with the pheromone and thus interfering with the mating orientation of the males. Development of methods for using the pheromones in traps to anticipate outbreaks of the pests for timing of insecticide applications appears promising. A cheap simple trap requiring no power source has been developed promising simple and efficient monitoring of adult populations of *Heliothis* spp. with the synthetic pheromones of the tobacco budworm and the bollworm. Ovicides are promising for the bollworm-tobacco budworm complex but egg scouting techniques are slow and inaccurate. Hopefully, adult traps baited with pheromones will solve the problem of timing ovicides and encourage the development of adulticides.

A related approach has been the search for chemicals that will disrupt the chemical communication between sexes. Researchers have shown that the attractiveness of female tobacco budworms is greatly reduced if certain organic chemicals are released into the environment. However, results of these studies are preliminary.

Researchers have reported that the male tobacco budworm when preparing to mate with a female produces a substance that suppresses her emission of the sex pheromone, but no work has been done on isolating the active agent. It is possible that such substances would be useful in combination with some of the previously noted techniques.

Results of recent research have shown that certain egg and larval parasites of *Heliothis* spp. are attracted to the host by host-seeking stimulants named kairomones.

Cottonseed oil baits have been used with *Baculovirus heliothis* to insure ingestion of the virus by the bollworm complex.

Tarnished plant bug.--In the early 1970's a researcher at USDA's Bioenvironmental Insect Control Laboratory at Stoneville, Miss., found that the female tarnished plant bug produced a substance that was attractive to males.

Genetic Control

Research on genetic control of cotton insects has centered on the sterile-insect release approach that was so successful against the screwworm fly, *Cochliomyia hominivorax* (Coquerel). In this approach large numbers of insects are reared and exposed to ionizing irradiation or to chemosterilants to induce sterility; then they are released among native populations at sufficient ratios to insure a high proportion of sterile matings. Development of this technique includes devising methods for rearing and sterilizing large numbers of insects with minimum effect on their competitiveness in securing mates, for shipping them from the rearing facility to release sites and releasing them so that they disperse among the native population, and for monitoring the effectiveness of the program. Frequently, preliminary applications of other population reduction measures, such as insecticides, are needed to reduce native populations to levels low enough so that an effective overflooding ratio can be achieved.

Boll weevil.--Much research has been conducted on sexually sterilizing the boll weevil. Effective doses of gamma irradiation reduced competitiveness and resulted in high mortality. Similar results were obtained with some of the chemosterilants. Finally, workers at several laboratories found that busulfan could achieve sterility in the male when incorporated into the adult diet for a 6-day feeding period. The long feeding period was a disadvantage, and another shortcoming of busulfan was that it did not sterilize the female. Thus, in the Pilot Boll Weevil Eradication Experiment the weevils had to be sexed for use of the sterile-male component. Sexing has to be done manually and is therefore laborious and costly. In an elimination program, the cost of sexing would be prohibitive. An intensive effort was then made to find a chemosterilant effective against both sexes. A combination of a 4-day feeding of busulfan-treated diet to adults plus a few hours of fumigation with hempa appeared to satisfactorily sterilize both sexes. However, research continued because the long holding and feeding period needed to be reduced or eliminated. The method of sterility used in the Boll Weevil Eradication Trial consisted of placing newly emerged adults on medicated diet slabs, irradiating them with 10,000 rads in a nitrogen atmosphere in a 137 C_s (Cobalt) source on the sixth day and then dipping them in acetone containing 0.1 percent diflubenzuron.

Bollworm and tobacco budworm.--A great deal of research has been done on methods of sterilizing *Heliothis* spp. and on the effects of various aspects of sexual competitiveness. Gamma irradiation has been pursued most extensively because it is relatively easy to use and presents minimum environmental hazards when proper equipment is used.

A limited field test of this method against the bollworm, conducted on St. Croix, U.S. Virgin Islands, in the early 1970's, was only partially successful because of problems with rearing. More extensive tests were conducted on the same island in 1972-74. The results of these tests

indicated that released mass-reared insects, whether irradiated or not, competed poorly for native mates, especially the males. However, populations of the bollworm were reduced to very low levels because the sterile females mated earlier in the night than the native females. The sterile males were essentially noncompetitive with the native males. Both types of males were ready to mate at any time of night; therefore, the native males mated with sterile females when the latter were ready. When the native females began mating later on, after the available native males had already mated, the sterile males mated with these females with little competition. Since populations of bollworms were limited to a few small plantings of corn on the island, relatively high ratios of sterile to native insects were achieved, and the population could be manipulated rather easily. It is questionable whether this procedure could be used on a large scale.

The test with the tobacco budworms showed that the sterile males were about 25 percent as competitive for mates as the native males were. This resulted from the mass-rearing conditions and irradiation. A lack of synchrony in mating times of sterile and native insects of both sexes was noted, thus making the system used against the bollworm ineffective in this case. Also, populations of the tobacco budworm were much larger and more widely distributed than those of the bollworm, with the result that the sterile-to-native insect ratios were generally too low (5 to 1) to have much impact on the native populations when the competitiveness problem was considered. Research is continuing on development of this method for use against the tobacco budworm, with emphasis on defining and overcoming problems related to the poor competitiveness of the sterile insects.

Hybrids were produced in the laboratory by crossing *Heliothis virescens* males and *H. subflexa* females. Males from these crosses were sterile and the females were fertile. These females, when mated to normal *H. virescens* males, produced sterile males and fertile females through subsequent backcross generations. Male sterility has persisted through backcross generations. This technique has potential to suppress or eliminate populations through male sterilization by releasing these females into the natural population. A pilot test to evaluate and perfect the technique was initiated in late 1977 on the Island of St. Croix, U.S. Virgin Islands. When backcross females were released on the Island, infusion of the sterility factor into the native population was obtained at some distance from a central release point in early 1979. About 50 percent of all males captured on the Island two generations after releases made in November and December 1979 on the western one-third of the Island were backcross (sterile) males. More than 20 percent of the males were backcross males for eight generations after release. A full release program was initiated in September 1980. Four separate releases of backcross insects, with the last one being an all-island release at a rate of 9 backcross:1 wild, resulted in a backcross frequency in the population on the island of about 95 percent for several months post release. Comparison of post release populations on St. Croix with those of preceding years on that island and with those of a neighboring island, Vicques, demonstrated suppression of the population with the sterile-male release technique on St. Croix.

Pink bollworm.--Gamma irradiation for sterilizing pink bollworms has been under study for some time. Research continues, and doses have been reduced to 20 krd, which has improved competitiveness of treated males with

nonsterile males for females. The pink bollworm has been mass-reared in the Pink Bollworm Rearing Facility, Animal and Plant Health Inspection Service (APHIS), USDA, Phoenix, Ariz., since 1967. Migrants from the Imperial and Coachella Valleys have been detected in relatively low numbers in certain localities of the San Joaquin Valley in California each year since 1967. Sterile moths have been released in these localities each year since 1968. Approximately 100 million were released annually from 1970 through 1973, but rearing problems reduced the numbers released in 1974. Moth releases which included some contract moths have since increased as follows: 150 million in 1975, 194 million in 1976, 412 million in 1977, 456 million in 1978, 637 million in 1979, and 510 million in 1980. The release apparently prevented establishment of infestations in this important cotton producing valley until a large number of storm-carried native moths were trapped late in the 1976 season. Large numbers of native moths were trapped in 1977 (7,402). A few larvae found in cotton bolls indicated that a low-level infestation occurred in the San Joaquin Valley. The sterile insect releases were continued during the growing seasons of 1978, 1979, and 1980. No additional larval infestations were found until 1980 when a total of nine larvae were found. Such treatment must continue until the pest is eliminated or reduced to very low levels in the Coachella and Imperial Valleys so they will no longer migrate to the San Joaquin Valley.

From November 1972 through 1976, sterile moths were released in the cotton off-seasons in the extreme southern tip of Florida to suppress pink bollworm populations in wild cotton growing in the area to the extent that the pink bollworm cannot migrate to the northern part of the State where cotton is grown. Unfortunately the moth releases had to be discontinued because of lack of funds. If elimination of the pink bollworm is undertaken in the future, the sterile-male release technique will no doubt be a major component in the program.

Host Plant Resistance

In the early days of the boll weevil when effective insecticides were not available, emphasis was given to cultural controls and early maturing cotton varieties, which made possible the production of a crop before the boll weevil could build up extremely high populations. With the advent of better insecticides and needs for higher yields, management practices exploited the full season potential of varieties grown in the rain belt and the irrigated areas of the West. Such production practices favored the boll weevil and pink bollworm, and though good yields were produced with the intensive use of insecticides, large populations diapaused in the fall, enhancing survival for infesting the subsequent crops and necessitating repetition of the control cycle year after year.

Boll Weevil.--When resistance to the organochlorine insecticides developed in the boll weevil in the mid-1950's, research attention was intensified in the development of alternative methods of controlling the boll weevil and other cotton insects. Though considerable effort was expended, progress in the development of varieties resistant to the boll weevil was slow. In the 1970's, Frego bract cottons, in which the bracts are distorted and do not envelop a square as is the case with normal bract cottons, reduced boll weevil oviposition by 50 percent or more when compared with normal bract

varieties. However, the reduction in oviposition has been considerably less than when the variety was grown under "no choice" situations. Frego bract varieties with acceptable agronomic characters might have a place in boll weevil control when field plantings are interspersed with trap crop plantings of normal bract cottons to attract overwintered weevils that could then be killed with insecticides. Although, Frego bract cottons are more susceptible to lygus bugs than normal bract cottons, breeders are making progress in solving the problem. Some short-season determinate cotton varieties are now grown extensively in Texas and have shown promise in reducing late-season insect damage, especially by the boll weevil. They also may help alleviate some of the damage caused by Heliothis spp. by maturing before the damaging late-season population peaks occur. Fast fruiting cultivars adapted to most of the rainbelt have been developed, but production systems to exploit them have not been widely adopted.

Bollworms.--the development of cotton varieties resistant to the tobacco budworm and bollworm has centered on three morphological characters of the cotton plant and on the development of early-maturing, determinate types of cotton that set the bulk of their fruit 2 to 3 weeks earlier than the non-determinate cottons that are usually grown commercially. Research is in progress, also, to develop cotton varieties resistant to the cotton flea-hopper, plant bugs, and the boll weevil, which would help alleviate the Heliothis spp. problem by reducing the insecticide applications for the former pests, thus, conserving the natural enemies of Heliothis spp.

The first of the morphological characters is lack of nectaries. Normal cottons have extrafloral nectaries on leaves and fruiting forms. The absence of these structures deprives Heliothis spp. adults of an important source of food when and where alternate food sources are not available. In controlled tests, the absence of extrafloral nectaries (nectariless cotton) resulted in at least 40 percent reduction in egg deposition and reduced longevity of adults.

The second character measurably reducing populations of Heliothis spp. is a smooth (glabrous) plant surface. Commercial cottons have 2,000 to 5,000 trichomes per square inch on the small terminal leaves and buds, which are the preferred oviposition sites of Heliothis spp. Glabrous stocks with less than 200 trichomes per square inch have reduced egg deposition by 50 percent.

The third character showing impact on Heliothis spp. populations is a high level of gossypol in the flower buds (squares). Gossypol content in buds of commercial cotton is about 0.5 percent, which affects larvae very little. However, larval mortality of 50 percent occurs when the gossypol level is 1.2 percent or higher.

Studies in field cages with cotton strains in which all three morphological characters have been combined showed that populations of the tobacco budworm increased about onefold in two generations, and those on glabrous plus high gossypol cotton or nectariless cotton plus high gossypol cotton increased twofold; meanwhile populations on commercial cotton increased tenfold to twelvefold. In field tests a glabrous cotton suppressed Heliothis spp. larval population 68 percent compared with the population on commercial cotton, and cottons with both the glabrous and high gossypol characters reduced larval populations 60 to 80 percent. In field tests with advanced strains, one strain with the glabrous-high gossypol combination yielded 700

pounds more seedcotton per acre than did a commercial variety. The nectariless cotton could not be properly evaluated in the field because the size of the plots was too small to prevent moths from obtaining food outside the plots.

In 1974 a nectariless cotton strain was released to commercial seed companies and has been made available to growers for large-scale planting. However, unless this cotton is planted on a community-wide basis and alternative sources of food are not available for moths, its effectiveness against Heliothis spp. could be limited. The glabrous character incorporated in the nectariless cotton strain promises to increase effectiveness against Heliothis spp.

Cotton Fleahopper.--Cottons with the glabrous character are well advanced and could be expected to have considerable impact on Heliothis spp. when available to growers. However there is a complication with these cottons. Although it has been demonstrated that these cottons have a significant impact on infestations of the cotton fleahopper as well as on infestations of Heliothis spp., it has also been suggested that these cottons are actually more sensitive to fleahopper attack than are most hirsute strains and, despite lower infestation levels, suffer greater damage. However, this damage may result from infestations of leafhoppers rather than cotton fleahoppers. Until these problems are resolved and overcome, the use of glabrous cotton may be questionable.

Cottons with the high gossypol character or those with this character combined with other resistant characters also show a great deal of promise against Heliothis spp. Recently it was demonstrated that they confer some resistance against the cotton fleahopper, and they have produced yields above those of current commercial varieties. However, it will probably be several years before these varieties are available to the grower in any quantity.

Lygus Bugs.--The nectariless character in cotton has reduced reproduction of lygus bugs, with considerably fewer nymphs developing on nectariless plants than on plants with nectaries. Apparently, the leaf nectaries are an important food source for the developing nymphs.

Pink bollworm.--'AET 5', a desirable upland breeding stock previously demonstrated as being resistant to the pink bollworm has been combined with other known resistant characters such as nectariless, smoothleaf, okraleaf, and early maturity. It compared favorably in yield with Deltapine and Stoneville. The resistance mechanisms were identified in free-choice and no-choice tests as antixenosis or nonpreference for oviposition and antibiosis in boll content.

Other Insects.--Research on the development of varieties resistant to the cotton leafperforator, and spider mites is in progress, and some success has been attained against spider mites.

Glandless Cultivars.--Cotton cultivars that produce seed without gossypol are available and are grown in some areas. Meal or roasted kernels from these cultivars enhance the value of cottonseed as a high protein food for humans and other nonruminants. Such cottons are more susceptible to assorted

general feeding insects, but the hazard is not prohibitive if they are carefully scouted for insects and appropriate action is taken.

Biological Control

Predators, parasites, and diseases play an important role in the control of insect pests of cotton. Cotton-pest control programs should maximize the role of natural enemies by utilizing insecticides, cultural practices, and other agents and techniques in augmentative ways. The key role of naturally occurring biological control agents must not be ignored in modern pest control programs. Wherever possible, an attempt should be made to evaluate the role of beneficial insects in the field. Some predaceous and parasitic insects of prime importance are discussed here.

Predators.--*Orius insidiosus* and *O. tristicolor* (Anthocoridae, Hemiptera), often called minute pirate bugs or flower bugs, are voracious predators of eggs and first-instar larvae of the bollworm, thrips, and other small insects. Populations often build up in such crops as corn and grain sorghum. Other Hemipterous insects, the big-eyed bugs, *Geocoris pallens*, *G. punctipes*, and *G. uliginosus*, are common predators of eggs and small larvae of the bollworm as well as other Lepidoptera, mirids, and aphids. Damsel bugs of the genus *Nabis* are efficient predators of a wide range of prey, including mirids, leafhoppers, aphids, and eggs and larvae of Lepidoptera. They attack bollworms as large as the second instar. Assassin bugs, particularly the genus *Zelus*, feed freely on eggs and larvae of Lepidoptera, including the bollworm, tobacco budworm, and cabbage looper. These bugs are usually less abundant in cottonfields than those referred to previously. *Podisus maculiventris* is a common stink bug that preys on large bollworms and other caterpillars.

Larvae of green lacewings, *Chrysopa* spp. (Chrysopidae, Neuroptera), are important predators of eggs and small larvae of bollworm and other Lepidoptera and of many soft-bodied insects.

Ground beetles of the family Carabidae (Coleoptera) have considerable potential as predators in the cottonfield, but knowledge is lacking on the habits and factors affecting abundance of the many species. Lady beetles, (family Coccinellidae) are common predators in cottonfields. The large species, including *Coleomegilla maculata*, *Hippodamia convergens*, and *Coccinella novemnotata*, feed on eggs and small larvae of the bollworm and other Lepidoptera and on aphids. Some smaller species in the genus *Scymnus* and all *Stethorus* spp. are primarily predators of mites. *Collops* beetles (Malachiinae in the family Melyridae) are often very abundant in cotton. They reportedly feed on the eggs and small larvae of the bollworm and other lepidopterous species.

Many families of Diptera contain species that are predaceous as adults or larvae. Best known as predators in cottonfields are the larvae of syrphid flies that prey primarily on aphids.

Family Formicidae (Hymenoptera), includes many predaceous species of ants. *Iridomyrmex pruinosus* is a regular predator of bollworm eggs. Other hymenopterous insects, the paper-nest wasps, *Polistes* spp., and solitary wasps of the genera *Zethus*, *Eumenes*, *Rygchium*, and *Stenodynerus*, provide their young in the nests with lepidopterous larvae. Wasps of the genus *Sphex* nest in the ground and provide their young with grasshoppers and related insects.

All spiders are predaceous, and many species are common in cottonfields. Orb weavers capture many moths in their webs. Wolf spiders and lynx spiders capture moths and other insects. Larvae and adults of the bollworm and boll weevil are among the prey of jumping spiders. Some species of thrips and mites are predators.

Judgments on predation are often difficult to make. The black fleahopper complex, *Spanagonicus albofasciatus* (Reuter) and *Rhinocloa forticornis* (Reuter) are predaceous but also feed on small squares. The cotton fleahopper, *Pseudatomoscelis seriatus* (Reuter) is better known as a pest from its feeding on terminal buds and small squares, but it is also a predator. The red imported fire ant, *Solenopsis invicta* Buren, is an effective cottonfield predator, especially of the boll weevil, but it is a vexing nuisance of some medical importance. Phytophagous insects, such as thrips, aphids, fleahoppers, and leafhoppers are pests at high populations but are important food for predators. Low-level populations should be tolerated or even encouraged.

Parasites.--Numerous species of hymenopterous parasites of several families are of great value in the biological control of most pests of cotton. These parasites vary tremendously in size, behavior, ecology, and host preference. Within their ranks, however, effective or potentially effective parasites of nearly every developmental stage, egg through adult, of the majority of cotton pests may be found. Many of them occur naturally in great numbers in certain geographical areas. Some are now and many will eventually have to be augmented in the field by habitat management or mass-release techniques so as to concentrate their populations at the time and in the place required for most effective control.

Flies of the family Tachinidae are parasites primarily of larvae of Lepidoptera and Coleoptera. Several species are of value as parasites of cotton pests and should be examined with the same goals in mind as those mentioned above; that is, augmentation through laboratory or field practices.

Native predators and parasites are often highly effective against bollworms, beet armyworms, tobacco budworms, cabbage loopers, cotton leafworms, cotton leafperforators, saltmarsh caterpillars, aphids, cutworms, lygus bugs, spider mites, whiteflies, and certain other pests. Diversified crops and uncultivated areas serve as refuge and reservoir areas for predators and parasites and, unfortunately, for some pests.

Releases of large numbers of green lacewing larvae in field experiments in Texas controlled heavy infestations of bollworms. Augmentation of food for lacewings has shown promise in California experiments. Releases of two species of introduced parasites have shown promise for control of the pink bollworm. However, much additional research is needed to develop such techniques into practical control measures. In addition, there are exotic species of predators and parasites of potential value in controlling both native and introduced cotton pests in the United States. Additional research is needed to locate and introduce them and to evaluate their potential in pest control.

Diseases.--Naturally occurring outbreaks of polyhedral viruses sometimes substantially reduce bollworm, tobacco budworm, cabbage looper, and cotton leafworm populations. These viruses can be produced on hosts mass-reared on artificial diets. *Bacillus thruingiensis* is a naturally occurring insect pathogen that is produced commercially. Naturally occurring fungi often

give control of spider mites and some species of insects. (See "Insecticides and Miticides Recommended for Cotton-Pest Control" for additional information on these diseases.)

Chemical Defoliation and Desiccation

Chemical defoliation and desiccation of cotton aid in the control of many cotton insects. These practices check the growth of the plants and accelerate the opening of bolls, reducing the damage and the late-season buildup of boll weevils, bollworms, tobacco budworms, and pink bollworms that would otherwise remain to infest next year's crop. They also prevent or reduce damage to open cotton by heavy infestations of the cotton aphid, cotton leafworm, and white-flies. However, defoliants and desiccants should not be applied until all bolls to be harvested are sufficiently developed to avoid losses in yield and quality. Stalks should be destroyed and other cultural practices followed. (See "Cultural Practices.")

Guides for the different defoliants and desiccants are issued by the Cooperative Extension Services of the various States. They contain information concerning the influence of plant activity, stage of maturing, and effect of environment on the efficiency of the process and give details relating to the various needs and benefits. They explain how loss in yield and quality of products may be caused by improper timing of the applications. Local and State recommendations should be followed.

Production Mechanization in Insect Control

Increased mechanization improved the efficiency of cotton production and insect control. High-clearance sprayers and dusters and aircraft have proved very useful and satisfactory for the application of insecticides and defoliants, especially in rank cotton. Tractors also enable the grower to use shredders, strippers, mechanical harvesters, and larger, better plows--all of which help in the control of the pink bollworm and, to some extent, the boll weevil. However, the flaming operation for weed control is of questionable value in insect control.

Mechanical harvesting with spindle pickers may result in leaving more infested cotton in the field than handpicking does, thus increasing the potential overwintering pink bollworm population. On the other hand, the use of strippers to harvest the crop is highly desirable from the standpoint of pink bollworm control, because all open bolls are stripped from the plants and are transported to the gin where a high percentage of the larvae are killed in the ginning process. Stalk shredders not only destroy certain insects, particularly the pink bollworm, but enable the cotton growers over wide areas to destroy the stalks before frost and thereby stop the development of late generations of this insect and the boll weevil, bollworm, and toabcco budworm.

The increased use of mechanized equipment for cotton production has resulted in large acreages of uniform, even-aged stands in some areas. These factors tend to simplify cotton-insect control. Hibernation quarters in or immediately adjacent to the fields are frequently eliminated by these modern cultivation practices.

Insecticides and Miticides

Precautions

Hazards and precautions in the use of insecticides and miticides are discussed in this section. All insecticides, of course, are toxic. On the other hand, when the enviable safety record associated with the use of many millions of pounds of insecticides on cotton annually is considered, it becomes evident that, if common-sense precautions are observed, insecticides can be used with relative safety. This applies to the operator, farmworker, and cotton checker. These precautions will insure the safety of fish and wildlife, honey bees, our food and feed supply, and the public in general.

Problems involving exposure of man, domestic animals, crops, fish, beneficial insects, and wildlife have been intensified by the increased use of insecticides for the control of cotton insects. The precautions, recommended amounts, and registration numbers are given on labels of all materials legally offered for sale. These materials should not be used unless the user is prepared to follow directions on the labels.

In handling any insecticides, avoid contact with the skin and the inhalation of dusts, mists, and vapors. Wear clean, dry clothing, and wash hands and face before eating or smoking. Launder clothing daily. Avoid spilling the insecticide on the skin, and keep it out of the eyes, nose, and mouth. If any is spilled on the skin, wash it off immediately with soap and water. If you spill it on your clothing, remove the clothing immediately, and wash the contaminated skin thoroughly. Launder clothing before wearing it again. If the insecticide gets in the eyes, flush them with plenty of water for at least 5 minutes and get medical attention.

Insecticide injury to man may occur through skin absorption or by oral or respiratory intake. Some solvents used in preparing solutions or emulsions are flammable, and most of them are toxic to some degree. In considering the hazards to man, it is necessary to distinguish between immediate hazards (acute toxicity) and cumulative hazards (chronic toxicity).

Insecticides used on cotton, in all forms, must be handled with care at all times. The physiological activity of organophosphorus compounds in both insects and warmblooded animals is primarily inhibition of the enzyme, cholinesterase. Initial or repeated exposure to them may reduce the cholinesterase level to the point where symptoms of poisoning may occur. These symptoms include headache, pinpoint pupils, blurred vision, weakness, nausea, abdominal cramps, diarrhea, and tightness in the chest. The symptoms may occur without forewarning. Applicators and handlers of these chemicals should be thoroughly aware of and familiar with the symptoms and the need to seek medical attention.

The toxicity of experimental compounds suggested for further testing may not be well known. Extreme precautions should be observed in their use until more information is available concerning their toxicity.

Formulations that have been accepted by the EPA under experimental permits are required to show prominently on the front panel of the label "For Experimental Use Only" and should be utilized only for such purposes.

The following insecticides can be used without special protective clothing or devices, although malathion may be absorbed through the skin and inhaled in harmful amounts. In all cases, follow the label precautions.

acephate
Bacillus thuringiensis
dicofol
malathion
sulfur
trichlorfon

The following insecticides can be absorbed directly through the skin in harmful quantities. When working with these insecticides in any form, take extra care not to let them come in contact with the skin. Wear protective clothing and respiratory devices as directed on the label.

chlorpyrifos
diazinon
dimethoate
endosulfan
ethion
methidathion
naled
propargite
toxaphene

The following chemicals are highly toxic and may be fatal if swallowed, inhaled, or absorbed through the skin. These highly toxic materials should be applied only by persons who are thoroughly familiar with their hazards and who will assume full responsibility for proper use of the chemicals and comply with all the precautions on the labels.

aldicarb
azinphosmethyl
carbophenothion
demeton
dicrotophos
disulfoton
endrin
EPN
methamidophos
methomyl
methyl parathion
monocrotophos
parathion
phorate
phosphamidon

Prevent skin absorption.--Many insecticides are almost as toxic when in contact with the skin as when taken orally. Such contact may occur through spillage or the deposition of fine mist or dust during application of insecticides. With the exception of aerosols, agricultural sprays and dusts have relatively large particles. When such particles are inhaled, they do not reach the lungs but are eventually brought into the throat and swallowed. Skin absorption constitutes a major route of entry, and yet it is the source of insecticide injury most likely to be ignored. Liquid concentrates are particularly hazardous. Load and mix them in the open. If you spill a concentrate on your skin or clothing, remove the contaminated clothing immediately, and wash the skin thoroughly with soap and water. Launder clothing before wearing it again. Contaminated shoes are a serious hazard. Launder work clothes, and change shoes daily. When recommended, wear natural or other suitable rubber gloves while handling highly toxic compounds. Have a change of clothing and soap and water at hand in the field. Bathe at the end of the work period.

Prevent oral intake.--Keep food away from direct contact with all insecticides, and also keep it away from the possible fumigant action of volatile chemicals. Wash exposed portions of the body thoroughly before eating or drinking. Do not smoke or otherwise contaminate the mouth area before washing the face and hands. Do not measure or store pesticides in containers that

might be mistaken for food containers. Store pesticides in the original containers only, with legible labels attached.

Prevent respiratory intake.--If called for on the label, wear a respirator or mask of a type that has been tested and found to be satisfactory for protection against the particular insecticide used. Decontaminate the respirator between operations by washing it and replacing the felts or cartridges or both at recommended intervals of use. Information on respirators certified for protection against insecticides may be obtained from the National Institute for Occupational Safety and Health, Testing and Certification Laboratory, 944 Chestnut Ridge Road, Morgantown, W.V. 26505.

Determine blood cholinesterase levels.--Regular users of organophosphorus compounds should have their blood cholinesterase levels checked before the start of a season's work and periodically thereafter. Do not use atropine as a preventive for organophosphorus poisoning. Another antidote for phosphorus poisoning is 2-PAM, which must be administered under the supervision of a physician. Be sure the local physician is familiar with the treatment and has the antidote on hand before large-scale application has begun. Speed of proper treatment is essential. (See "Information on poison control centers" in this section.)

Most carbamates are also inhibitors of cholinesterase, and regular users of these chemicals should be checked and treated as above, with one exception: 2-PAM and other oximes are not recommended. These compounds are referred to as rapidly reversing inhibitors of cholinesterase. The reversal is so rapid that unless special precautions are taken the measurements of blood cholinesterase of human beings or animals treated with these compounds are likely to be inaccurate and always in the direction of appearing to be normal. The blood cholinesterase inhibition should be measured by a technique that minimizes reactivation.

Dispose of excess materials and used containers.--Excess dust or spray materials should be buried. The burial sites for excess insecticides, wastes, equipment washings, and containers should be selected with care and so situated that contamination of ground water does not occur. When possible, growers should carry their empty insecticide containers to a sanitary landfill dump and have them buried. Inform the dump operator of the nature of the residues in the containers. Some States require that they be buried at a designated place. Empty metal containers should be smashed beyond the possibility of reuse and buried.

Handle materials in the field carefully.--Metal containers of emulsifiable concentrates carried to the field should be placed in the shade. Agitation of closed containers left in the sun can result in pressure buildup in the container, with a resultant explosion of the contents when the top is removed.

Store insecticides properly.--Insecticides should be stored in a separate, fireproof building to avoid contamination of food, feedstuffs, or fertilizers. Care should be taken, also, to avoid cross-contamination of pesticides and herbicides. Unused insecticides should be kept in the original

container and stored in places inaccessible to children, irresponsible persons, or animals. All insecticides should be stored under lock and key.

Procedures for applicators of insecticides.--Airplane pilots who are to apply insecticides should not assist in mixing or loading operations. Persons making ground application of organophosphorus insecticides or loading aircraft with them should always be accompanied by at least one other person in the field.

Information on poison control centers.--A publication entitled "Directory of Poison Control Centers" is available upon request from the Bureau of Chemical Hazards, Consumer Products Safety Commission, 5401 Westbard Avenue, Bethesda, MD 20016. It lists facilities in each State that provide to the medical profession, on a 24-hour basis, information concerning the prevention and treatment of accidents involving exposure to poisonous and potentially poisonous substances. The telephone directory may also list poison control centers for the local area.

Misapplication or drift of insecticides.--Spraying or dusting should be done under proper conditions and in such a manner as to avoid direct application or drift to adjacent fields where animals are pastured, to food or feed crops in the field, or to residential areas, canals, streams, waterways, or highways. Usually there is less drift from sprays than from dusts and from ground applications than from aerial applications. Injury from misapplication or drift is usually determined to be the responsibility of the applicator and farmer.

Residues in plants and soils.--In the development of new insecticides, the possibility of deleterious residues remaining in cottonseed and seed products must be thoroughly investigated. (See section entitled "Restrictions.")

Excessive insecticide residues in the soil may affect germination, rate of growth, and flavor of crops. Concentration of the residue is influenced by the insecticide, the formulation used, amount applied, type of soil, and climatic conditions. Illegal residues have occurred in some root crops and in soybeans grown in rotation with cotton treated with organochlorine insecticides.

Protect predators and parasites.--Predators and parasites play an important role in the control of cotton insects. Most currently available insecticides destroy these beneficial insects as well as harmful ones; therefore, the control program used should take maximum advantage of natural and cultural controls. Insecticides that are selective for the pest species concerned and of minimum detriment to the beneficial species should be used. When regular inspections show that high populations of predators and parasites are present, deferring of insecticide treatments should be considered.

Protect honey bees.--Every year pesticides applied to cotton cause extensive losses of honey bees. Much of this damage is needless and can be averted without reduced control of injurious pests if proper precautions are taken. Bees are beneficial to cotton, and many cottongrowers as well as

their neighbors grow legumes and other crops that require pollination. For the benefit of the beekeeper, the cottongrower, and agriculture in general, every effort should be made to protect pollinating insects. Table 2 shows the relative toxicity to honey bees of insecticides used for the control of cotton insects.

Bee losses can be reduced if the following general precautions are taken:

1. If a pesticide must be used, choose the one least hazardous to bees that will control the harmful pests.
2. If a hazardous material must be used, apply it when bees are not visiting the field.
3. Use sprays instead of dusts. Application with ground equipment is less hazardous to bees than application by airplane.
4. Avoid drift of pesticide into the apiary or onto adjacent crops in bloom.
5. Reduce the number of applications to an absolute minimum.
6. Advise the beekeeper to locate the apiary out of the usual drift path of the pesticide from the field.
7. Give the beekeeper advance notice if a hazardous material must be used, so he may move or otherwise protect the bees.
8. Remind the beekeeper that confining the bees during and after a single application may prevent or reduce damage, and that colonies can be confined under wet burlap tarpaulins up to 2 days. Confinement is not practical if repeated applications are to be made.

Protect fish and wildlife.--Recommended precautions must be followed to reduce hazards to fish and wildlife when using insecticides for control of cotton insects. It is especially important to avoid direct application or drift to ponds, streams, standing water, and weedy areas. Wherever possible, cottonfields should be located away from ponds. Runoff from treated fields should be diverted from fish ponds. Where drift may create a problem, sprays are preferred to dusts, and ground applications are preferred to aerial applications. Do not discard pesticides or clean pesticide application equipment in or near streams or ponds.

Additional safeguards.--Equipment that has been used for mixing and applying 2,4-D and other weedkillers should never be used for mixing and applying insecticides to cotton because of the danger of crop injury resulting from contamination of the equipment.

Registration

Before a pesticide may be legally shipped in interstate or intrastate commerce, it must be registered under the Federal Insecticide, Fungicide, and Rodenticide Act as amended 1978, administered by the Environmental Protection Agency (EPA). Scientific data are required to establish that the pesticide, when used as directed on the label, will control the target pest and will not cause unreasonable adverse effects to man and his surroundings. The criteria for registration are strict and subject to constant review as new information is developed. Many States have similar registration regulations. Under the new law the Administrator of EPA is given the authority to proceed against

Table 2.--Relative toxicity to honey bees of insecticides used for control of cotton insects

Group 1.--Materials highly toxic to bees exposed to direct treatment or residues	Group 2.--Materials toxic to bees when visiting field at time of application	Group 3.--Materials relatively low in toxicity to bees
aldicarb	carbophenothion	*Bacillus thuringiensis*
azinphosmethyl	demeton	chlordimeform
carbaryl	disulfoton	-----
chlorpyrifos	endosulfan	dicofol
diazinon	endrin	ethion
dicrotophos	methomyl (spray)	propargite
dimethoate	phorate	sulfur
EPN	trichlorfon (dust)	toxaphene
malathion	-----	trichlorfon
methamidophos	-----	-----
methidathion	-----	-----
methomyl (dust)	-----	-----
methyl parathion	-----	-----
monocrotophos	-----	-----
naled	-----	-----
parathion	-----	-----
phosphamidon	-----	-----

persons or individuals who engage in misusing pesticides by applying them in a manner "inconsistent with their labeling." In addition, the Administrator may place pesticides in a "restricted use" category, thus subjecting them to controls in distribution and ultimately requiring their use only by certified applicators.

Cottonseed is classified as a food product. The undelinted seed as it comes from the gin is the "raw agricultural commodity." Where pesticide-use patterns will result in residues of the original material or of toxic metabolites on or in cottonseed or its byproducts, Maximum Residue Limits (MRL), or tolerances, must be established. The establishment of MRL tolerances in raw agricultural commodities is the responsibility of EPA. A registration will not be granted until a MRL of residue has been granted. Finite tolerances or exemption from tolerances are required for all pesticides registered for use on cotton.

Restrictions

Any regulations established by the Federal or State Governments will take precedence over those given in this report, which are as follows:

1. Workers entering cottonfields within 2 days after treatment with endrin or methyl parathion should wear clean, tightly woven protective clothing.
2. Do not repeat applications of dimethoate within 14 days of each other.

3. Do not apply disulfoton to cotton more than twice per season or repeat application within 21 days of each other.

4. Do not repeat applications of monocrotophos within 5 days of each other.

5. Do not apply endosulfan, ethion, phorate, or propargite after bolls begin to open. Dosages of toxaphene in excess of 4 pounds per acre per application should not be applied to cotton after bolls open.

6. If cottonfields are to be grazed, observe grazing restrictions on the labels of all insecticides used on the crop.

7. Unused cottonseed intended for planting that has been treated with any insecticide should not be used for food or feed. Treated seed must bear a statement on the label indicating that the seed has been treated with the chemical and should be used for planting only.

The following insecticides have a field-reentry time after application of at least the interval indicated:

1 day--azinphosmethyl, EPN, ethion, and phosphamidon
2 days--carbophenothion, demeton, dicrotophos, endrin, methyl parathion, monocrotophos, oxydemetonmethyl, and parathion

The minimum number of days that should elapse between the time of the last insecticidal application and harvest for certain insecticides is as follows:

Hand harvest--
2 days--azinphosmethyl in ultra-low-volume applications
4 days--naled
5 days--endrin, methyl parathion
7 days--parathion

Hand or mechanical harvest--
1 day--azinphosmethyl
3 days--EPN
7 days--trichlorfon
14 days--diazinon, dimethoate, dicofol, chlorpyrifos, acephate, phosphamidon
15 days--methomyl
21 days--monocrotophos, demeton
28 days--disulfoton, phorate
30 days--dicrotophos
60 days--methidathion

The tolerances (parts per million) established for various insecticides recommended for cotton-insect control in or on cottonseed are as follows: acephate, 2.0; aldicarb, 0.1; azinphosmethyl, 0.5; carbaryl, 5; carbophenothion, 0.2; chlordimeform, 5; chlorpyrifos, 0.5; demeton, 0.75; diazinon, 0.2; dicofol, 0.1; dicrotophos, 0.05; diflubenzuron, 0.2; dimethoate, 0.1; disulfoton, 0.75; endosulfan, 1; endrin, 0; EPN, 0.5; ethion, 0.5; fenvalerate, 0.2; malathion, 2; methamidophos, 0.1; methidathion, 0.2; methomyl, 0.1; methyl parathion, 0.75; monocrotophos, 0.1; naled, 0.5; parathion, 0.75; permethrin, 0.5; phorate, 0.05; phosmet, 0.1; phosphamidon, 0.1; profenofos, 3; propargite, 0.1; sulprofos, 0.5; toxaphene, 5; and trichlorfon, 0.1.

Bacillus thuringiensis and the nuclear polyhedrosis viruses are exempt from the requirements of a tolerance, and sulfur is a material not requiring a tolerance.

Some States have special restrictions on the use of certain insecticides. Check your State and local regulations.

Application

Formulations

Most insecticides and miticides commonly used for control of cotton pests may be readily formulated into either sprays or dusts. Stable formulations of some materials are very difficult to make. Research on formulations continually provides more satisfactory material with greater stability.

Dusts.--Most organic insecticides and miticides formulated in dusts with talc, clay, calcium carbonate, phyrophyllite, diatomaceous earth, or sulfur as the carrier give good control of cotton insects and spider mites. The value of formulations with proper dusting characteristics is to be emphasized. Erratic results and poor control are sometimes caused by inferior formulations, although poor results caused by improper application or timing are frequently blamed on formulations. Some dusts containing high percentages of sulfur have undesirable dusting properties and may present a fire hazard.

Sprays.--The term "low volume" is used for the application of concentrated insecticides when the total volume of spray applied is more than one-half gallon but less than 10 gallons per acre. The term "ultra-low volume" is used for the application of concentrated or technical insecticides when the total volume of spray liquid applied is one-half gallon or less per acre.

Control of cotton insects and spider mites has been highly successful with properly formulated sprays applied at rates ranging from 1 to 15 gallons per acre. Most of the organic insecticide sprays used on cotton are made from emulsifiable concentrates. It is recommended that all insecticide formulators show conspicuously on the label the pounds of actual toxicant per gallon in emulsifiable concentrates. The pounds of toxicants specified should be consistent with the required label declaration of active ingredients. Occasional foliage injury has resulted from poorly formulated concentrates or when the spray was improperly applied. Emulsifiers and solvents should be tested for phytotoxicity before they are used in formulations. Phytotoxicity of emulsions may be aggravated by high temperatures, high concentrations, drying winds, and highly alkaline water. Diluted sprays should be applied immediately after mixing and should not be held for later use.

Ultra-low-volume aerial applications of azinphosmethyl, endosulfan, malathion, and methyl parathion are approved for control of certain insects. A mixture of malathion plus methyl parathion is approved for boll weevil and bollworm control in the boll-weevil-infested States. Some progress has been made in applying other compounds in this manner and in developing ground equipment for their application. Results of limited research indicate that some materials perform differently when applied as ultra low-volume technical materials or as emulsifiable concentrates than when applied as emulsions. Because performance cannot be predicted, each insecticide applied in this

manner must be tested thoroughly against various cotton pests. Hazards and residues from such applications must be considered. Expanded research is needed to develop this method of applying insecticides to control cotton insects.

The addition of blackstrap molasses at 1/2 to 2 gallons per acre to insecticidal sprays has improved bollworm control. Molasses increases palatability of spray residues to bollworm larvae and extends the residual effectiveness of certain insecticides. Other benefits include increased kill of bollworm moths and a probable reduction in drift because of increased droplet weight and reduced evaporation.

Granules, fertilizer-insecticide mixtures, and seed treatments.--Granular formulations of insecticides and mixtures of insecticides and fertilizers are used for control of some soil insects. They are being used for whitefringed beetle and wireworm control in some areas. Granular formulations of some systemic insecticides are being used in some areas against certain foliage-feeding pests. Systemic insecticides are sometimes applied as dusts or liquids to cottonseed before planting for early-season insect control. Such treatments sometimes adversely affect stands and seedling vigor. Granular or emulsifiable formulations of some systemic insecticides are applied in the seed furrow at planting for control of certain early-season insects.

Mixtures of two or more insecticides.--When more than one insect or spider mite is involved in a control program, insecticides are frequently combined to give control of the species involved. Bollworm, cotton aphid, and spider mite buildup frequently follows application of some insecticides, and for this reason suitable insecticides or miticides are added to some formulations.

Where an outbreak of aphids or spider mites is involved, a recommended organophosphorus insecticide may be used alone or may be combined in a boll weevil-bollworm formulation.

Emulsifiable concentrates of two or more insecticides may be formulated into the recommended sprays in the field. When this is done, however, the quantity of solvent is increased, which may in turn increase the phytotoxicity hazard and toxicity to man and animals.

Mixtures containing less than recommended dosages of each of several insecticides have frequently been unsatisfactory and are not recommended.

Equipment

Insecticides may be applied to cotton with either ground or aerial equipment. Generally, sprays and dusts are equally effective. Regardless of the equipment chosen, effective control is obtained only when applications give thorough coverage and are properly timed. Improperly timed or unnecessary applications may result in a pest complex that can cause greater damage to the cotton crop than the original target insect.

Ground application.--High-clearance rigs usually make efficient application possible in rank cotton with little mechanical injury to plants. Ground machines should be calibrated to apply the proper dosages for the speeds at which they will be operated.

For dust applications the nozzles should be adjusted to approximately 10 inches above the plants, with one nozzle over each row. Dusts are usually applied at 10 to 20 pounds to the acre except in the Far West, where heavier dosages are required. Results of research in Arkansas show that the total volume can be reduced to as little as 2 pounds of dust per acre with no loss in control if the amount of needed active ingredient is applied.

For spraying seedling cotton under conditions of straight and uniform row spacing, one nozzle per row is suggested. As the cotton grows, the number of nozzles should be increased to two or in rank growth to as many as five or six in some areas. Nozzles without drops, spaced 20 inches apart on the boom, are used in some areas. The nozzles should be adjusted to approximately 10 inches above the plants and be capable of delivering from 1 to 15 gallons per acre.

Emulsifiable concentrates should be diluted immediately before use. Some type of agitation, generally the bypass flow, is necessary during the spray operation to insure a uniform mixture. As a safety measure, the spray boom should be located behind the operator.

Aerial application.--In aerial application of sprays with fixed-wing aircraft, booms and nozzles should be adjusted to give uniform coverage across the swath with the greatest possible concentration of droplets in the desirable size range. Booms should not extend to the wing tips. The aircraft should be flown at a height of 5 feet above the crop for most effective insecticide placement and minimal drift. Fly-in clinics to assist aerial applicators in solving problems are proving to be effective and popular.

Emulsifiable concentrates should be mixed with water immediately before use and delivered at 1 to 10 gallons per acre on a maximum swath width of 40 feet. Ultra-low-volume concentrates should be applied at up to one-half gallon per acre on a swath width of 35 to 75 feet, depending on weather and other conditions. Dust applications should be made on a 40-foot maximum swath width. When insect populations are extremely heavy, it may be advantageous to narrow the swath width.

A method of flagging or marking the swaths should be used to insure proper distribution of both sprays and dusts.

Timing

Correct timing is essential for satisfactory control of cotton insects. Consideration must be given to the overall populations and stages of both beneficial and harmful insects rather than to those of a single insect. The stage of growth of the cotton plant and expected yield are important. Since the use of insecticides often induces outbreaks of aphids, bollworms, spider mites, and other pests, insecticides should be applied only when and where needed.

Early-season applications should be made to control beet armyworms, cutworms, darkling ground beetles, grasshoppers, or other insects which threaten to reduce a stand. Recommendations for early-season applications to control aphids, plant bugs, boll weevils, cotton fleahoppers, and thrips vary greatly from State to State. Differences in the infestations of these insects, as well as in many other production factors, make it inadvisable to attempt to standardize recommendations for early-season control.

It is generally recommended that suitable insecticides be applied to cotton during its maximum period of fruiting and maturing if infestations threaten to reduce the yield, affect quality, or delay maturity. Recommendations for insecticide treatments are similar throughout the Cotton Belt, but certain details differ from State to State, and often within a State. The appropriate State "Guide for Controlling Cotton Insects" should be followed.

Effect on Cotton Plants

Many insecticides affect cotton plants physiologically, and certain solvents and additives may enhance the adverse effects of insecticides or may cause physiological effects of their own. The effects may result in delayed or advanced crop maturity with or without accompanying yield loss. Several organochlorine insecticides often cause earlier plant maturity, which is a physiological response by the cotton plant. Many organophosphorus compounds and the carbamate aldicarb used as seed or soil treatments have an effect on cotton plants expressed in more vigorous vegetative growth early in the season, resulting in taller plants and larger leaves, which can be related to physiological responses. Results have ranged from increased yield and early maturity to reductions in yield and delayed maturity at various locations in the Cotton Belt. The use of organophosphorus and carbamate insecticides at planting has often resulted in delayed plant emergence and poor stands.

Reductions in yield and delays in crop maturity have resulted when early-season foliar application schedules of several organophosphorus compounds have been used. However, more work has been done with methyl parathion, and its adverse effects are clearly documented under field conditions. The use of methyl parathion at rates greater than 0.5 pound per acre may result in reduced fruit retention. Though plants usually compensate for such fruit loss through production of added fruiting points, the result is delayed crop maturity and, in some cases, reduced yield. The most severe adverse effects of methyl parathion occur from frequent early-season applications. When methyl parathion is used only as needed, delayed maturity or yield loss is minimized. Results with carbaryl in California suggest similar reductions in fruit retention without compensating fruiting to offset fruit loss.

The effects of several insecticides on growth and fruiting of plants are not consistent from one location to another and from year to year at any particular location. Adverse effects appear to be more common in some areas. Growers and insect-control advisers should be aware of the potential adverse effects of insecticides on crop production. Insecticide use should be based on expected benefits from insect control weighed against possible losses in yield or delay in maturity if it is not used. Researchers should make a greater effort to distinguish between the growth and fruiting responses of plants caused by insecticides or those resulting from control of insects obtained with them.

Recently, in the absence of insects, increases in yield have resulted from mid- and late-season applications of EPN plus methyl parathion, acephate, and chlordimeform.

Determining the Need for Chemical Control

The determination of pest population levels is fundamental in carrying out a sound cotton-insect control program. Entomologists recognize this basic principle and accept the professional obligation for implementing it. The need for control measures should be based on insect-infestation counts.

Insecticides or miticides are recommended for the control of injurious insect and spider mite pests of cotton when their populations reach the level at which economic losses will result if they are not controlled. This can result in the immediate loss of the fruiting forms (squares and bolls) or damage to the plant in such manner that fruiting will be delayed to the extent that a full crop cannot be made during the normal growing season. In areas subject to summer droughts or where the growing season is short, any insect injury causing damage to the extent that fruiting is delayed or early fruit is lost can result in reduced yields. The control of even a light infestation of injurious insects early in the season under these conditions may be important. In much of the Cotton Belt, however, the cotton plant usually is able to overcome early plant damage and early loss of fruit with little or no reduction in yield. In these areas, the need for protecting early fruit and for hastening maturity is minimized.

Some farmers have learned to recognize certain harmful and beneficial insects and certain insect diseases. They can determine by field inspections when an insecticide is needed, and by referring to the State Guide they can select the proper one to use. Other farmers prefer to employ persons who are specially trained to do the job for them. Many growers employ specially trained personnel, sometimes referred to as checkers or scouts, to make insect-population counts and infestation records in cottonfields. The majority of the scouts are college students or former college students with some entomological background who have been given special training by the extension entomologist or by county agents. According to most farmers who have employed them, money spent for this purpose is a sound investment. The saving of one insecticide application during the year when infestation counts show that it is not needed, or the timely application of one that is needed, usually more than pays the entire cost of the service for the season.

Two uses of persons specially trained to make insect-population counts and infestation records in cottonfields have developed. In one, the farmer hires the person to make the records and to submit them to him. The farmer then determines the need for insecticides, selects those to be used from the State Guide, and either applies them with his own equipment or arranges with a custom applicator to do it for him. In the other type of use the farmer contracts with a consulting entomologist for the complete job of insect control. The consultant may have several individuals making population counts and infestation records for him. His experience enables him to use the records to determine the need for the insecticide. He makes the selection from the State Guide and either arranges directly for its application or leaves this to the discretion of the owner or manager, depending on the terms of the contract.

Both types of such trained persons have proved highly satisfactory to growers using them, and their use is increasing. With increased emphasis on reduction in cost of producing cotton and on decreased use of insecticides to avoid residues and other hazards, the precise knowledge of insect conditions and the wise use of insecticides are essential. The employment of trained persons usually is the best way to assure that the job will be properly done.

A pest management program funded by the U.S. Department of Agriculture was initiated in 1972, continued in 1973, and completed in 1974 to encourage cotton producers to use cultural and biological pest-control measures in combination with insecticides as needed to protect their crops from damage by insects. The on-farm cotton-pest management program was carried out by the Cooperative State Extension Services and APHIS in cooperation with the State departments of agriculture, experiment stations, cotton producers, and other industry leaders. The Extension Service and APHIS were responsible for the program on the national level. From 1975 to 1981 Federal funds were provided to the Cooperative State Extension Services in cotton-producing States to develop pest management programs. An Optimum Pest Management program conducted in Panola County, Miss., concurrently with the Boll Weevil Eradication Trial conducted in North Carolina and Virginia was initiated in 1978 and completed in 1980. It had Federal funding, with the Mississippi Cooperative Extension Service serving as the operational agency.

Scouting and Consulting

A high percentage of the cotton acreage is scouted for insect populations and pest damage as a guide for use of insecticide or other appropriate action. Some programs are publicly sponsored, usually by the Cooperative Extension Services, while others are private enterprises. After field counts are made, action decisions are made by farmers, county extension agents, publicly employed scouts, or independent pest management consultants. Scouting-consulting is encouraged. Research on methods to improve the speed and accuracy of estimates of insect populations and damage is needed. Computers can be used to process large amounts of field data on a current basis. The development of professionalism among pest management consultants, individually and through associations, is commendable.

Cotton-Pest Resistance to Insecticides and Miticides

Resistance to insecticides and miticides is the ability in insect and spider mite strains to withstand exposure to dosages that exceed that of a normal susceptible population--such ability being inherited by subsequent generations of the strain. The resistance of cotton pests to insecticides has developed rapidly in recent years (table 3). Since 1947, when organic chemicals began to have wide usage in cotton, 25 species of insects and spider mites that attack the crop are known to have developed resistance, and several other species are strongly suspected of having developed resistance. One or more of these resistant species occur in localized areas in most cotton-producing States from California to North Carolina. Most pest resistance is to the organochlorine insecticides, but four species of mites and the beet armyworm, bandedwing whitefly, bollworm, and tobacco budworm are known to be resistant to some organophosphorus compounds.

The resistance of cotton pests to recommended insecticides is a serious problem. It emphasizes the importance of using every known means possible to alleviate the difficulty to the extent that control may be maintained. This includes the use of pesticides having different physiological modes of action from those to which resistance has been developed and in the use of cultural practices, especially early stalk destruction, in reducing populations of

boll weevil and the pink bollworm. Every possible advantage of biological control agents should be utilized, and where there is a choice, chemicals that are of minimum detriment to beneficial insects should be used.

Table 3.--Pests resistant to certain insecticides in one or more areas of various States

Pest	Insecticide	States
Bandedwing whitefly	Methyl parathion	Arkansas, Louisiana, Tennessee.
Beet armyworm	Organochlorine compounds.	Arizona, Arkansas, California, Mississippi.
Do	Methyl parathion	Alabama, Arkansas.
Boll weevil	Organochlorine compounds.	Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas.
Bollworm	DDT	Alabama, Arkansas, Arizona, California, Florida, Georgia, Louisiana, Mississippi, Missouri, Oklahoma, North Carolina, Tennessee, Texas.
Do	Endrin	Arkansas, Louisiana, Mississippi, Oklahoma, Tennessee, Texas, California.
Do	Carbaryl	Arizona, Louisiana, Oklahoma, Texas.
Do	Methyl parathion	Arkansas, Mississippi, Oklahoma.
Do	TDE	Texas.
Do	Toxaphene plus DDT	Do.
Do	Strobane plus DDT	Do.
Do	Methomyl	Louisiana.
Cabbage looper	DDT	Arizona, Georgia, Tennessee, Texas.
Do	Organochlorine compounds.	Alabama, Arkansas, California, Louisiana, Mississippi, Oklahoma.
Do	Endrin and toxaphene	Arizona.
Do	Organophosphorus compounds.	Arkansas, Louisiana, Mississippi.
Cotton aphid	Benzene hexachloride	Arkansas, Alabama, Georgia, Louisiana, Mississippi, Tennessee.
Cotton fleahopper	Organochlorine compounds.	Texas.
Do	Organophosphorus compounds.	Do.

Table 3.--Pests resistant to certain insecticides in one or more areas of various States--Continued

Pest	Insecticide	States
Cotton leafperforator.	Organochlorine compounds.	California.
Do	DDT	Arizona.
Cotton leafperforator.	Organophosphorus compounds.	California, Arizona.
Cotton leafworm	Organochlorine compounds.	Arkansas, Louisiana, Texas.
Lygus bugs, *Lygus hesperus*.	do	California.
Do	Trichlorfon and monocrotophos.	Do.
Do	Malathion	Do.
Do	DDT	Arizona.
Pink bollworm	DDT	Durango and Coahuila, Mexico; Texas.
Saltmarsh caterpillar	Toxaphene, DDT, and endrin.	Arizona, California.
Southern garden leafhopper.	DDT	California.
Spider mites:		
Tetranychus turkestani	Organophosphorus compounds, except phorate seed or soil treatment.	Alabama, California.
T. cinnabarinus	do	Alabama, Arizona, California, Texas.
T. pacificus	do	Do.
T. urticae	do	Alabama, Arkansas, California, Louisiana, Mississippi, North Carolina.
T. pacificus	Dicofol	California.
T. urticae	do	Do.
Stink bug: *Euschistus conspersus*.	Organochlorine compounds.	Do.
Thrips:		
Frankliniella, mixture of species.	Dieldrin	Do.
Do	Endrin	California, Georgia.
Frankliniella occidentalis.	Toxaphene	New Mexico.
Do	Organochlorine compounds.	Texas.
Thrips tabaci	do	Do.

Table 3.--Pests resistant to certain insecticides in one or more areas of various States--Continued

Pest	Insecticide	States
Tobacco budworm	Carbaryl	Alabama, Arizona, Arkansas, California, Georgia, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Texas.
Tobacco budworm	DDT	Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, Texas.
Do	Endrin	Alabama, Arizona, Arkansas, California, Florida, Georgia, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Texas.
Do	Strobane plus DDT	Arkansas, Texas.
Do	TDE	Do.
Do	Toxaphene plus DDT	Arkansas, Louisiana, Mississippi, Texas.
Do	Methomyl	Arizona, Arkansas, Louisiana, Mississippi.
Do	Organophosphorus compounds.	Alabama, Arizona, Arkansas, California, Florida, Georgia, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas.
Do	Carbaryl	Florida.

Effect of Environmental Factors on Chemical Control

Failures to control insects are often attributed to ineffective insecticides, poor formulations, poor applications, improper timing, and resistance to insecticides. Variations in humidity, rainfall, temperature, sunlight, and wind influence the effectiveness of an insecticide applied to plants. These variations also influence the development of insect populations and plant growth. The inability of the applicator to maintain a regular application schedule because of excessive rains or high winds often results in loss of control at a critical period.

A combination of an adverse effect on the toxicity of the insecticide and a favorable effect on growth of the plant and insect population may result in failure to obtain control. Conversely, conditions favorable to the insecticide and plants and adverse to the insect population will result in very effective control. The use of fertilizer and supplemental irrigation,

although valuable in cotton-production programs, may create conditions that make insect control difficult. Also certain insects, in particular the boll weevil, become more difficult to kill with some insecticides as the season progresses. Therefore, one should consider all factors before arriving at a decision as to the specific one responsible for the failure to obtain control.

Insecticides and Miticides Recommended for Cotton-Pest Control

Materials recommended for the control of pests in one or more States are discussed in this section (see table 4). In some areas certain pests have become resistant to one or more of the materials recommended. (See "Cotton-Pest Resistance to Insecticides" for details.) One asterisk (*) indicates an organochlorine compound; two asterisks indicate an organophosphorus compound.

**Acephate.--Acephate will control bollworms, tobacco budworms, cabbage loopers, cotton aphids, lygus bugs, thrips, spider mites, and whiteflies.

Aldicarb.--Aldicarb in granular form applied in the furrow at planting will control thrips, cotton aphids, cotton fleahoppers, leafminers, spider mites, lygus bugs, and overwintered boll weevils feeding on foliage. Side-dress applications when plants begin to square will control leafhoppers, cotton fleahoppers, boll weevils, spider mites, and lygus bugs but may result in an increase in subsequent bollworm and tobacco budworm infestations. Treatments at planting may result in phytotoxicity under some conditions to the extent that stands may be damaged. Stand reduction can be avoided by limiting in-furrow applications to no more than 1 pound of active ingredient per acre and using an "at plant" fungicide where seedling disease is prevalent. Aldicarb applied in-furrow at planting or as a sidedressing must be covered completely with soil. It is toxic to fish, wildlife, and birds. It should be kept out of any body of water, and care should be taken not to contaminate water when cleaning equipment or disposing of wastes. Birds and wildlife may be killed if allowed to feed on exposed granules. Aldicarb is highly toxic to man and animals and should be used with adequate precautions.

**Azinphosmethyl.--Azinphosmethyl will control cotton aphids, boll weevils, brown cotton leafworms, cotton leafperforators, cotton leafworms, fleahoppers, garden webworms, lygus bugs, pink bollworms, stink bugs, and thrips. Erratic results have been obtained against the cotton aphid and spider mite in some areas. It is ineffective against the beet armyworm and the saltmarsh caterpillar. Azinphosmethyl is highly toxic to man and animals and should be used with adequate precautions.

Bacillus thuringiensis.--*Bacillus thuringiensis* will control low to moderate infestations of the cabbage looper, the bollworm, and tobacco budworm. It is used primarily in pest management programs.

Baculovirus heliothis.--*Baculovirus heliothis* will control low to moderate infestations of bollworms and tobacco budworms. It is used primarily in pest management programs.

Carbaryl.--Carbaryl will control boll weevils, bollworms, tobacco budworms, cotton fleahoppers, cotton leafworms, cotton leafperforators, cutworms,

darkling beetles, fall armyworms, false celery leaftiers, field crickets, garden webworms, grasshoppers, leaf rollers (Platynota stultana), lygus bugs, pink bollworms, saltmarsh caterpillars, southern garden leafhoppers, stink bugs, and thrips. It does not control beet armyworms, black fleahoppers, cabbage loopers, false chinch bugs, or spider mites. Aphids do not usually build up following its use, but spider mites often do.

Table 4.--Common and chemical names of insecticides used for cotton-pest control

[*Indicates a proprietary name]

Common name	Chemical name	Other designation
acephate	O,S-dimethyl acetylphosphoramidothioate.	Ortho 12,420; *Orthene.
aldicarb	2-methyl-2-(methylthio)propionaldehyde O-(methylcarbamoyl)oxime.	Union Carbide; 21149;UC 21149; *Temik.
azinphosmethyl	O,O-dimethyl S-[(4-oxo-1,2,3-benzotriazin-3(4H)-yl)methyl] phosphorodithioate.	*Guthion.
carbaryl	1-naphthyl methylcarbamate.	*Sevin.
carbophenothion	S-[[(p-chlorophenyl)thio]methyl] O,O-diethyl phosphorodithioate.	*Trithion.
chlordimeform	N'-(4-chloro-o-tolyl)-N,N-dimethylformamidine.	*Galecron; *Fundal.
chlorpyrifos	O-O-diethyl O-(3,5,6-trichloro-2-pyridyl) phosphorothioate.	*Lorsban.
demeton	O,O-diethyl O(and S)-[2-(ethylthio)ethyl] phosphorothioate.	*Systox; mercaptophos.
diazinon	O,O-diethyl O-(2-isopropyl-6-methyl-4-pyrimidinyl)phosphorothioate	*Spectracide.
dicofol	4,4'-dichloro-α-(trichloromethyl)benzhydrol.	*Kelthane.
dicrotophos	dimethyl phosphate ester of (E)-3-hydroxy-N,N-dimethylcrotonamide.	*Bidrin.
diflubenzuron	N-[(4-chlorophenyl)amino]carbonyl-2,6-difluorobenzamide.	*Dimilin, TH6040.
dimethoate	O,O-dimethyl S-(methylcarbamoylmethyl) phosphorodithioate.	*Rogor; *Cygon.
disulfoton	O,O-diethyl S-[2-(ethylthio)ethyl] phosphorodithioate.	*Di-Syston; thiodemeton.
endosulfan	6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-6,9-methano-2,4,3,-benzodioxathiepin 3-oxide.	*Thiodan.
endrin	1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo-endo-5,8-dimethanonaphthalene.	Compound 269.

Table 4.--Common and chemical names of insecticides used for cotton-pest control--Continued

[*Indicates a proprietary name]

Common name	Chemical name	Other designation
EPN	O-ethyl O-(p-nitrophenyl) phenylphosphonothioate.	EPN 300.
ethion	O,O,O',O'-tetraethyl S,S'-methylene bis(phosphorodithioate).	*Nialate.
fenvalerate	cyano(3-phenoxyphenyl)methyl 4-chloro-α-(methylethyl)= benzeneacetate.	*Pydrin.
malathion	O,O-dimethyl phosphorodithioate of diethyl mercaptosuccinate.	*Cythion.
methamidophos	O,S-dimethyl phosphoramidothioate.	*Monitor; *Tamaron.
methidathion	O,O-dimethyl phosphorodithioate S-ester with 4-(mercaptomethyl)-2-methoxy-Δ^2-1,3,4-thiadiazolin-5-one.	*Supracide; *Ultracide.
methomyl	S-methyl N-[(methylcarbamoyl)oxy]thioacetimidate.	*Lannate; *Nudrin.
methyl parathion	O,O-dimethyl O-(p-nitrophenyl) phosphorothioate.	*Metacide; *Wofatox.
monocrotophos	dimethyl phosphate ester with (E)-3-hydroxy-N-methylcrotonamide.	*Azodrin.
naled	1,2-dibromo-2,2-dichloroethyl dimethyl phosphate.	*Dibrom.
oxydemeton-methyl	S-[2-(ethylsulfinyl)ethyl] O,O-dimethyl phosphorothioate.	*METASYSTOX-R.
parathion	O,O-diethyl O-(p-nitrophenyl) phosphorothioate.	*Thiophos; *Niran.
permethrin	(3-phenoxyphenyl)methyl 3-(2,2-dichloroethenyl)-2,2-dimethylcyclopropanecarboxylate.	FMC 33297; *Pounce; *Ambush PP557.
phenamiphos	ethyl 4-(methylthio)-m-tolyl isopropylphosphoramidate.	*Nemacur.
phorate	O,O-diethyl S-[(ethylthio)methyl] phosphorodithioate.	*Thimet.
phosphamidon	2-chloro-2-diethylcarbamoyl-1-methylvinyl dimethyl phosphate.	*Dimecron.
propargite	2-(p-tert-butylphenoxy)cyclohexyl 2-propynyl sulfite.	*Comite; *Omite.
sulfur	sulfur	----------
sulprofos	O-ethyl O-[4-methylthio)phenyl] S-propyl phosphorodithioate.	*Bolstar; Bay NTN 9306.
toxaphene	chlorinated comphene containing 67% to 69% chlorine.	Camphechlor.
trichlorfon	dimethyl (2,2,2-trichloro-1-hydroxyethyl) phosphonate.	*Dipterex; *Dylox.

**Carbophenothion.--Carbophenothion will control cotton aphids, cotton fleahoppers, cotton leafperforators, lygus bugs, thrips, and most species of spider mites. It appears to have long residual activity. It is not effective against the bollworm, boll weevil, or cabbage looper and is erratic against saltmarsh caterpillars and stink bugs. Carbophenothion is highly toxic to man and animals and should be used with adequate precautions.

Chlordimeform.--Chlordimeform will control beet armyworms, bollworms, tobacco budworms, cotton leafperforators, pink bollworms, spider mites, thrips, and western yellowstriped armyworms. Its action is primarily ovicidal, and it is presently labeled only as an ovicide for *Heliothis* spp. control. It was withdrawn from the market in late 1976 but is now available for use in a closed aerial application system.

**Chlorpyrifos.--Chlorpyrifos will control bollworms, boll weevils, cotton aphids, cotton fleahoppers, cutworms, fall armyworms, lygus bugs, pink bollworms, tobacco budworms, thrips, saltmarsh caterpillars, and spider mites.

**Demeton.--Demeton is both a contact and a systemic insecticide with long residual systemic activity. When applied as a foliage spray, it is effective against most species of aphids and spider mites for 2 to 8 weeks and controls the southern garden leafhopper and thrips. Demeton does not control boll weevils, bollworms, cotton leafworms, grasshoppers, or pink bollworms. Demeton is highly toxic to man and animals and should be used with adequate precautions.

**Diazinon.--Diazinon spray will control cotton fleahoppers, cotton leafperforators, lygus bugs, saltmarsh caterpillars, and thrips.

*Dicofol.--Dicofol is an acaricide with little insecticidal activity. It will control most species of spider mites. For best results spray should be applied at a minimum of 20 gallons per acre with nozzles directed to give coverage under the leaf. Dicofol sprays applied from airplanes have given erratic results.

**Dicrotophos.--Dicrotophos spray will control cotton aphids, cotton fleahoppers, cotton leafperforators, false chinch bugs, lygus bugs, spider mites, saltmarsh caterpillars, stink bugs, and thrips. Dicrotophos is highly toxic to man and animals and should be used with adequate precautions.

Diflubenzuron (Dimilin).--Diflubenzuron will suppress boll weevil populations at 0.0625 pound active ingredient per acre. It is particularly effective in reducing egg hatch from overwintering females. The toxicity of this compound is not fully known but extreme caution should be observed in its use. (This compound was granted conditional registration by EPA in 1979.)

**Dimethoate.--Dimethoate spray will control cotton aphids, cotton fleahoppers, lygus bugs, and thrips.

**Disulfoton.--Disulfoton as a seed treatment or in granular or spray form applied in the furrow at planting will control aphids, leafminers, spider

mites, and thrips for 4 to 6 weeks after planting. Treatments at planting may result in phytotoxicity under some conditions to the extent that stands may be damaged and early growth retarded. Phytotoxicity hazards may be greater where preemergence herbicides are used. Phytotoxicity hazards are also greater where certain fungicide combinations are used as planterbox treatments with the seed. Planting seed should be treated only by custom operators who are able to treat seed adequately and uniformly with suitable precautions against hazard to operators. Disulfoton is highly toxic to man and animals and should be used with adequate precautions.

*Endosulfan.--Endosulfan will control bollworms, tobacco budworms, cabbage loopers, cotton leafperforators, lygus bugs, stink bugs, and thrips.

*Endrin.--Endrin will control beet armyworms, boll weevils, bollworms, brown cotton leafworms, cabbage loopers, cotton leafperforators, cotton leafworms, cutworms, darkling ground beetles, fall armyworms, false chinch bugs, field crickets, flea beetles, fleahoppers, garden webworms, grasshoppers, greenhouse leaftiers, lygus bugs, stink bugs, tobacco budworms, thrips, and yellowstriped armyworms. Endrin used in a seed treatment will protect seed and young seedlings from seedcorn maggots, false wireworms, and wireworms. It will not control the pink bollworm or spider mites. Aphids usually do not build up after applying endrin but spider mites sometimes do. Endrin should not be used for control of cotton insects where soybeans are grown in rotation with cotton. EPA has canceled registration for use of endrin on cotton in all areas east of interstate Highway 35 and has listed restrictions for its use in areas west of interstate Highway 35. Endrin is highly toxic to man and animals and should be used with adequate precautions.

**EPN.--EPN will control boll weevils, bollworms, and tobacco budworms. EPN is highly toxic to man and animals and should be used with adequate precautions.

**Ethion.--Ethion will control cotton aphids, cotton leafworms, and most species of spider mites.

Fenvalerate (Pydrin).--Fenvalerate will control beet armyworms, bollworms, boll weevils, tobacco budworms, cotton leafperforators, thrips, whiteflies, and pink bollworms at 0.05 to 0.2 pound per acre, and cabbage loopers and fall armyworms at 0.1 to 0.2 pound per acre. Spider mite infestations may develop following its use. Ordinary precautions are recommended in its use.

**Malathion.--Malathion spray will control boll weevils, cotton aphids, brown cotton leafworms, cotton leafperforators, cotton leafworms, fall armyworms, cotton fleahoppers, garden webworms, grasshoppers, lygus bugs, southern garden leafhoppers, thrips, and some species of spider mites. Results against whiteflies have been erratic. It will not control the bollworm or saltmarsh caterpillar. In some areas 0.5 pound of malathion at 3-day intervals gave boll weevil control comparable to that obtained at 4- to 5-day intervals with higher dosages. Dust formulations have not been entirely satisfactory in some areas, probably because of instability. Malathion applied by airplane in ultra-low-volume sprays at 0.5 to 1.25 pounds per acre controls the boll weevil.

**Methamidophos.--Methamidophos will control beet armyworms, boll weevils, bollworms, cabbage loopers, cotton aphids, cotton leafperforators, lygus bugs, saltmarsh caterpillars, spider mites and thrips. Methamidophos is highly toxic to man and animals and should be used with adequate precautions.

**Methidathion.--Methidathion will control bandedwing whiteflies, spider mites, boll weevils, bollworms, lygus bugs, pink bollworms, and tobacco budworms. In a schedule of applications it may be phytotoxic.

Methomyl.--Methomyl will control beet armyworms, bollworms, tobacco budworms, cabbage loopers, cotton leafperforators, lygus bugs, and pink bollworms. It may be phytotoxic when repeated applications are used. A safened dust is less phytotoxic than sprays. Methomyl is highly toxic to man and animals and should be used with adequate precautions.

**Methyl parathion.--Methyl parathion will control beet armyworms, boll weevils, bollworms, cabbage loopers, cotton aphids, cotton leafperforators, cotton leafworms, cutworms, fall armyworms, false chinch bugs, fleahoppers, garden webworms, grasshoppers, lygus bugs, pink bollworms, southern garden leafhoppers, saltmarsh caterpillars, stink bugs, tobacco budworms, thrips, yellowstriped armyworms, and certain species of spider mites. Methyl parathion has a short residual toxicity. For late-season boll weevil control a dosage of 0.25 pound at 3-day intervals is preferred over higher dosages at longer intervals. Although it is unsatisfactory for control of most species of spider mites, methyl parathion in a boll weevil schedule suppresses them. An encapsulated formulation of methyl parathion has shown promise against the boll weevil, bollworm, and cabbage looper at 0.5 to 1.0 pound per acre. Methyl parathion is highly toxic to man and animals and should be used with adequate precautions.

**Monocrotophos.--Monocrotophos will control bandedwing whiteflies, beet armyworms, boll weevils, bollworms, cabbage loopers, cotton aphids, cotton fleahoppers, cotton leafperforators, lygus bugs, pink bollworms, some species of spider mites, saltmarsh caterpillars, stink bugs, thrips, and tobacco budworms. This is a water-soluble formulation, and observations indicate that it washes off more readily by rain than an emulsifiable concentrate does. Monocrotophos will kill birds and other wildlife. It should be kept out of any body of water and should be applied only when weather conditions favor drift from areas being treated. Monocrotophos is highly toxic to man and animals and should be used with adequate precautions.

**Naled.--Naled will control cotton fleahoppers, cotton leafperforators, cutworms, grasshoppers, and lygus bugs. It is ineffective against the cabbage looper at 0.5 pound per acre and spider mites at 0.5 to 1.0 pound per acre.

**Oxydemeton-methyl.--Oxydemeton-methyl will control cotton aphids and most species of spider mites. This material is highly toxic to man and animals and should be used with adequate precautions.

**Parathion (ethyl).--Parathion will control brown cotton leafworms, most species of aphids, cabbage loopers, cotton leafperforators, cotton leafworms, fleahoppers, lygus bugs, false chinch bugs, saltmarsh caterpillars, serpentine leafminers, southern garden leafhoppers, stink bugs, some species of spider mites, and thrips. At dosages of 0.5 to 1.0 pound per acre it controls the boll weevil, bollworm, and tobacco budworm. Parathion is highly toxic to man and animals and should be used with adequate precautions.

Permethrin (Ambush and Pounce).--Permethrin will control bandedwing whiteflies, boll weevils, bollworms, tobacco budworms, cotton leafperforators, lygus bugs, pink bollworms, and thrips at 0.05 to 0.2 pound per acre and cabbage loopers at 0.1 pound per acre. Spider mite infestations may develop following its use. Ordinary precautions are recommended in its use.

Phenamiphos.--Phenamiphos applied in granular form in the furrow at planting will control thrips. Ordinary precautions are recommended in its use.

**Phorate.--Phorate as a seed treatment or applied in granular form in the furrow at planting will control aphids, leafminers, spider mites, and thrips for 4 to 6 weeks from planting date. Treatments at planting time may result in phytotoxicity under some conditions to the extent that stands may be damaged and early growth retarded. Phytotoxicity hazards may be greater where preemergence herbicides are used. Foliar applications of phorate will control spider mites. Phytotoxicity hazards are also greater where certain fungicide combinations are used as planter-box treatments with the seed. Planting seed should be treated only by custom operators who are able to treat seed adequately and uniformly with suitable precautions against hazard to operators. Phorate is highly toxic to man and animals and should be used with adequate precautions.

**Phosphamidon.--Phosphamidon will control cotton aphids, cotton fleahoppers, cotton leafperforators, false chinch bugs, lygus bugs and other mirids, and thrips. Phosphamidon is highly toxic to man and animals and should be used with adequate precautions.

Propargite.--Propargite will control the Pacific, strawberry, and twospotted spider mites.

Sulfur.--Sulfur has been widely used in dust mixtures for control of the cotton fleahopper and certain species of spider mites. When applied alone or in combination with insecticides in formulations containing 40 percent or more sulfur, it will control the desert and strawberry spider mites and will suppress other species. Precautions should be exercised in applying sulfur to cotton adjacent to cucurbits.

**Sulprofos (Bolstar).--Sulprofos will control the bollworm and tobacco budworm at 0.5 to 1.5 pounds and the beet armyworm and fall armyworm at 1.0 pound per acre. Sulpropos is highly toxic to man and animals and should be used with adequate precautions.

*Toxaphene.--Toxaphene will control beet armyworms, boll weevils, bollworms, cotton fleahoppers, cotton leafworms, cotton leafperforators, cutworms, fall armyworms, flea beetles, garden webworms, grasshoppers, lygus bugs, stink bugs, thrips, tobacco budworms, whitelined sphinxes, yellowstriped armyworms, and western yellowstriped armyworms. Toxaphene will not control cabbage loopers, pink bollworms, or saltmarsh caterpillars.

**Trichlorfon.--Trichlorfon spray will control beet armyworms, celery leaftiers, cotton leafperforators, cutworms, darkling beetles, fall armyworms, field crickets, flea beetles, fleahoppers, garden webworms, leafrollers (Platynota stultana), lygus bugs, western yellowstriped armyworms, stink bugs, saltmarsh caterpillars, southern garden leafhoppers, and yellowstriped armyworms. Trichlorfon has given erratic results against bollworms and cabbage loopers. It was not effective against thrips at 0.5 to 1.0 pound per acre. Occasionally trichlorfon has been phytotoxic. It should be applied immediately after it is mixed with water.

Insecticides and Miticides Showing Promise in Field Tests

The materials listed and discussed in this section have shown promise in the testing programs of the State Agricultural Experiment Stations and the U.S. Department of Agriculture. These materials are not recommended for grower use but are recommended to research workers for further testing and study. One asterisk (*) indicates a proprietary name; two asterisks indicate an organophosphorus compound.

AC 222,705 (Payoff) [(±)-cyano(3-phenoxyphenyl)methyl (+)-4-(difluromethoxy)-alpha-(1-methylethyl)benzeneacetate]

In field tests in 1978, 1979, 1980, and 1981 AC 222,705 showed promise against bollworms and tobacco budworms at 0.025 to 0.04 pound per acre and against boll weevils at 0.04 pound per acre. Ordinary precautions are recommended in its use.

BAY SIR 8514 (2-chloro-N-[[[4-(triflurornethoxy)phenyl]amino]carbomyl] benzamide).

In field tests in 1978, 1979, 1980, and 1981 the reduction of boll weevil emergence from squares treated with this compound was comparable with that of diflubenzuron. The toxicity of this compound is not fully known, but extreme caution should be observed in its use.

Carbofuran (*Furadan) (2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate)

Carbofuran applied in the seed furrow at planting in a granular formulation at 0.5 to 1.0 pound per acre showed promise against thrips. In field tests from 1964 through 1974, carbofuran applied as a foliar spray showed promise against bollworms, boll weevils, cotton aphids, cotton leafperforators, lygus bugs, bandedwing whiteflies, thrips, and tobacco budworms at rates of 0.5 to 1.0 pound per acre. Carbofuran is highly toxic to man and animals and should be used with adequate precautions.

Cypermethrin (PP 383) mixed isomers or (±)-[cyano(3-phenoxyphenyl) methyl] cis, trans-(±)-3-(2,2-dichloroethenyl)-2,2-dimethylcyclopropanecarboxylate)

In field tests in 1978, 1980 and 1981 this compound showed promise against the boll weevil, bollworm, and tobacco budworm at 0.05 and 0.12 pound per acre. Ordinary precautions are recommended in its use.

Fluvalinate (Zoecon ZR-3210 (cyano(3-phenoxyphenyl)methyl 2-2[[2-chloro-4-trifluoro-methyl phenyl]amino-3-3 methylbutanoate])

In field tests in 1979, 1980, and 1981, this material showed promise against boll weevils, bollworms, and tobacco budworms at 0.1 and 0.2 pound per acre. Ordinary precautions are recommended in its use.

NRDC-161 Decis (S)-[cyano(3-phenoxyphenyl)methyl] cis (+)-3-(2,2-dibromoethenyl)-2,2-dimethylcyclopropanecarboxylate)

In field tests from 1976 to 1978, and 1981, NRDC-161 in a spray showed promise against the boll weevil, bollworm, tobacco budworm, pink bollworm, and cotton leafperforator at 0.01 to 0.02 pound per acre. The toxicity of this compound is not fully known, but extreme caution should be observed in its use.

**Profenofos CGA-15324 (*Curacron) [(O)-4-bromo-2-chlorophenyl) O-ethyl S-propyl phosphorothioate]

In field tests in 1975 and 1976, this compound as a spray showed promise against the bollworm - tobacco budworm complex at 0.5 and 2.0 pounds per acre. In 1977, 1978, and 1979, it showed promise against this complex at 0.5 to 1.0 pound per acre. In 1976 and 1977 it showed promise against the beet armyworm and fall armyworm at 0.75 to 1.0 pound per acre. The toxicity of this compound is not fully known, but extreme caution should be observed in its use.

Rohm & Haas (RH-0994) or Stauffer (MV 770) (O-[4-(chlorophenylthio)phenyl O-ethyl s-propyl phosphorothioate])

In field tests from 1977 to 1981, RH-0994 in a spray showed promise against the bollworm and tobacco budworm at 0.5 to 1.0 pound per acre. The toxicity of this compound is not fully known, but extreme caution should be observed in its use.

Thiodicarb (Larvin) (dimethyl-N-N'[thiobis([methylimino)=carbonyl]oxy)] bis[ethonimidothioate])

In field tests from 1976 to 1981, this material showed promise as a spray against the bollworm and tobacco budworm at 0.5 to 1.0 pound per acre. In 1977 it showed promise against the beet armyworm, boll weevil, fall armyworm, and cabbage looper at 0.75 to 1.0 pound per acre. The toxicity of this material is not fully known but extreme caution should be observed in its use.

COTTON INSECTS AND SPIDER MITES AND THEIR CONTROL

The insects and spider mites injurious to cotton and the recommended chemicals and procedures for their control are discussed in this section.

Dosage ranges for insecticides recommended in one or more States for the control of cotton pests are also discussed. In local areas certain insects have become resistant to one or more of the insecticides recommended for general use, see "Cotton-Pest Resistance to Insecticides and Miticides" for details.

Beet Armyworm, Spodoptera exigua (Hbn.)

The following insecticides will control the beet armyworm in some areas at the indicated dosages of technical material:

Spray	Pounds (AI) per acre
Acephate	0.25-1.0
Methidathion	0.25-0.5
Methomyl	0.45-0.67
Methyl parathion	1.00-1.5
Monocrotophos	0.25-1.0
Trichlorfon	1.00

Corn meal and citrus pulp baits containing 1.25 or 2.5 percent methomyl applied at 20 pounds per acre have shown promise against beet armyworms. The beet armyworm often is a pest of seedling cotton, but it also attacks older plants. Squares and blooms may be destroyed, and feeding on the bracts may cause small bolls to shed. The beet armyworm has been a pest in the West and Southwest for many years. In the Mid-South and Southeast its occurrence in numbers is sporadic, but severe local outbreaks are not uncommon.

Boll Weevil, Anthonomus grandis Boheman

The boll weevil occurs in the cotton producing area encompassing the eastern two-thirds of Texas and Oklahoma and eastward to the Atlantic Ocean. Since 1960 it has extended its range to west Texas and poses a threat to cotton in New Mexico. Boll weevils found in cotton in northwestern Mexico and Arizona pose a threat to cotton production in New Mexico and California. This insect was found in California for the first time in 1965. Control programs initiated 18 years ago in west Texas are being continued to prevent further spread.

The effectiveness of insecticides approved for boll weevil control will vary not only in different localities but also with the season. The choice of insecticides will be determined by their effectiveness in the particular area where the insect is to be controlled. Dosages of technical material that have controlled the boll weevil in mid- and late-season in one or more areas are as follows (dosages lower than these are used for early-season control in some areas):

Spray	Pounds (AI) per acre
Azinphosmethyl[1/]	0.125-0.5
Carbaryl	0.8-2.0
Chlorpyrifos	1.0
EPN	0.25-0.5
EPN + methyl parathion	0.25+0.25-0.5
EPN + methyl parathion + chlorpyrifos	1.0+1.0+0.5
Fenvalerate	0.1-0.2
Malathion[1/]	0.5-1.2
Methomyl + methyl parathion	0.22+0.5
Methyl parathion[1/]	0.25-2.0
Monocrotophos	0.6-1.0
Parathion	0.25-1.0
Permethrin	0.1-0.2
Toxaphene	2.0-4.0
Toxaphene + methyl parathion	0.25-2.0+0.25-1.0
Toxaphene + methyl parathion + chlorpyrifos	2.0+1.0+0.5

1/ Azinphosmethyl, malathion, and methyl parathion may be applied ultra-low volume as technical material at 0.125 to 0.25 pound, 0.5 to 1.2 pounds, and 0.5 to 0.75 pound per acre, respectively.

When these insecticides are used for boll weevil control, other insect problems have to be considered. Infestations of cotton aphids, bollworms, spider mites, and tobacco budworms may develop when some of these insecticides are used alone. Spider mites may build up rapidly after the use of toxaphene or carbaryl. Careful checks should be made at 5- to 7-day intervals. If these pests are found to be increasing, control measures should be started at once. (See "Cotton Aphid, *Aphis gossypii* Glover", and "Spider Mites" in this section.)

Aldicarb is effective against overwintered boll weevils when used as an in-furrow granule application at planting at 0.6 to 1.0 pound (0.3 to 0.5 pound if hill-dropped) per acre.

Diflubenzuron will suppress boll weevil populations at 0.06 pound per acre. It is particularly effective in preventing egg hatch from overwintering females. Egg hatch from surviving females may resume within 7 days after treatments are discontinued necessitating a clean-up application of an organic phosphorus insecticide at that time.

Boll weevil control measures should be taken when definite need is established. Experience indicates that mid- and late-season control programs may require frequent applications. Fields should be inspected weekly until bolls are no longer susceptible to attack by weevils. Where early-season control is required, experience indicates that frequent treatments may also be needed during the period of abundance of overwintered weevils. Insecticide treatments should be based on actual need.

Certain chemical and cultural control procedures may be used during and immediately following cotton harvest to greatly reduce the overwintering boll weevil population. The boll weevil survives the winter as a diapausing adult. Most of the adults must feed on fruiting forms for approximately 10 days to 3 weeks to attain diapause. Very few weevils attain diapause when insecticides are applied for their control before cotton matures. Large

numbers of weevils attain diapause soon after the termination of the regular control program and before the food supply is destroyed, either by a killing frost or by chemical and mechanical methods. A proper combination of practices at this time, including applications of organophosphorus insecticides, defoliation, and stalk destruction to prevent the development of diapause by the weevils will reduce overwintering populations by approximately 90 percent.

In the Pilot Boll Weevil Eradication Experiment conducted in south Mississippi (see "Insect Attractants"), an effective component in the suppression program was a trap plot of cotton consisting of about 2 percent of the acreage in each field. The trap plot, planted some 2 weeks earlier than the remainder of the field, was planted by the grower. Its purpose was to attract overwintered boll weevils. An in-furrow application of 1 pound of aldicarb per acre was made at planting and a sidedressing of 2 pounds per acre when plants began to square to kill the weevils. Grandlure used in 100-foot-interval bait stations within the trap plot intensifies attraction to the weevils. If aldicarb is not used, a conventional insecticide must be applied at 5-day intervals after the plants in the trap plot begin to square to kill the overwintered weevils.

Bollworm, Heliothis zea (Boddie), and Tobacco Budworm, H. virescens (F.)

The bollworm and the tobacco budworm are the most common lepidopterous species that attack cotton. Several other species that cause boll injury, discussed elsewhere in this report, are the beet armyworm, fall armyworm, pink bollworm, yellowstriped armyworm, and western yellowstriped armyworm.

The bollworm and tobacco budworm occur throughout the Cotton Belt. The latter species has always been more difficult to control. Beginning in the 1960's, the tobacco budworm became extremely difficult to control in Texas and in the 1970's in Louisiana, Arkansas, Mississippi, and South Carolina as well.

Effective control of bollworms depends on the thoroughness and proper timing of insecticide applications. Frequent field inspections to determine the presence of eggs, young larvae, and square damage during the fruiting period are essential. For the most effective control, it is essential that insecticide applications be made when larvae are small.

In the 1960's available insecticides failed to control high populations of the tobacco budworm in Texas and Oklahoma. Similar control failures occurred in Arkansas and Louisiana in 1974; in some areas of Alabama, Mississippi, and South Carolina in 1975; and thereafter in the remaining cotton-producing States east of the Mississippi River, and in Arizona and in the Imperial Valley of California. Failures to control tobacco budworms with available insecticides are expected to increase in the future.

Dosages of technical material that have controlled bollworms in one or more areas are as follows:

Spray	Pounds (AI) per acre
Acephate	0.75-1.0
Bacillus thuringiensis	0.25-0.5
*Baculovirus heliothis*1/	0.12-0.25
Carbaryl	1.0-2.0
Chlordimeform2/	0.12-0.25
Chlordimeform + fenvalerate	0.125+0.1
Chlorpyrifos	1.0
Endrin3/	0.3-0.6
Endrin + methyl parathion3/	0.4+1.0
EPN	0.75-1.0
EPN + methyl parathion	0.25-1.0+0.5-1.0
EPN + methyl parathion + chlordimeform	0.5-1.0+0.5-1.0+0.125-0.25
EPN + methyl parathion + chlorpyrifos	0.5+0.5+0.5
EPN + methyl parathion + methomyl	0.5+0.5+0.125-0.33
Fenvalerate	0.1-0.2
Methomyl4/	0.45-0.67
Methyl parathion5/	1.0-2.0
Methyl parathion + methomyl	0.5-1.0+0.25
Monocrotophos	0.6-1.0
Parathion	1.0
Permethrin	0.1-0.2
Permethrin + chlordimeform	0.1+0.125
Sulprofos	0.5-1.5
Toxaphene	2.0-4.0
Toxaphene + methyl parathion	1.0-3.0+1.0-2.0
Toxaphene + methyl parathion + chlorpyrifos	2.0+1.0+0.5
Toxaphene + methyl parathion + chlordimeform	2.0-3.0+1.0-1.5+0.125+0.25
Toxaphene + methyl parathion + methomyl	1.0-2.0+1.0-1.5+0.125-0.33
Methomyl + fenvalerate	0.125+0.1
Methomyl + permethrin	0.125+0.1

1/ 36-72 larval equivalents per acre.
2/ Chordimeform is available only for restricted use in a closed aerial application system.
3/ West of Interstate Highway 35.
4/ Methomyl may be applied at 0.12-0.25 pound per acre as an ovicide.
5/ May be applied ultra-low volume at 0.5 to 0.75 pound per acre.

Cabbage Looper, *Trichoplusia ni* (Hübner)

The cabbage looper and related species are difficult to control with insecticides. The following materials applied at 5-day intervals have given control in one or more areas:

Spray	Pounds (AI) per acre
Acephate	0.75-1.00
Bacillus thuringiensis	0.25-0.5
Fenvalerate	0.1-0.2
Methamidophos	0.5-1.0
Methomyl	0.45
Monocrotophos	0.6-1.0
Permethrin	0.1-0.2

The cabbage looper is frequently controlled by viruses and fungi. When diseased loopers are commonly found, chemical control may be delayed or omitted.

Cotton Aphid, *Aphis gossypii* Glover

Heavy infestations of the cotton aphid may occur on cotton after the use of certain insecticides and on seedling cotton and sometimes on older cotton where no insecticides were applied. When aphid infestations are heavy and rapid kill is needed, any one of the following treatments is usually effective at the following dosages of technical material:

Spray	Pounds (AI) per acre
Azinphosmethyl	0.25
Carbophenothion	0.5-1.0
Chlorpyrifos	0.5-1.0
Demeton	0.125-0.38
Dicrotophos	0.1-0.375
Dimethoate	0.1-0.25
Endosulfan	0.6-1.0
Ethion	0.5
Malathion	0.5-1.25
Methamidophos	0.5-1.0
Methyl parathion	0.25-0.5
Monocrotophos	0.3
Oxydemeton-methyl	0.25-0.37
Parathion (ethyl)	0.1-0.5

The following materials are effective when used as seed treatments or as in-furrow granule applications at planting at the indicated dosages of technical material:

Insecticide	Pounds (AI) per acre
Aldicarb	0.3-0.5
Disulfoton	0.5-1.5
Phorate	0.5-1.5

Cotton Fleahopper, *Pseudatomoscelis seriatus* (Reuter)

The cotton fleahopper frequently attacks cotton in Texas and Oklahoma and, to a lesser extent, in other areas. It can be controlled with the following insecticides at the indicated dosages of technical material:

Spray	Pounds (AI) per acre
Azinphosmethyl	0.1-0.25
Carbaryl	0.25-1.40
Dicrotophos	0.1-0.25
Dimethoate	0.1-0.25
Malathion	0.7-1.25
Methyl parathion	0.12-0.5
Toxaphene	0.5-2.0
Trichlorfon	0.25-1.0

Aldicarb is effective when used as an in-furrow granule application at planting at 0.6 to 1.0 (0.3 to 0.5 if dill dropped) pound per acre.

The black fleahopper complex, *Spanagonicus albofasciatus* (Reuter) and *Rhinacloa forticornis* (Reuter), occurs on cotton in the irrigated West. The former species also occurs in the Mississippi Selta. More information is needed on both of thes species to clarify their roles as economic pests of cotton and as predators.

Cotton Leafperforator, *Bucculatrix thurberiella* Busck

The cotton leafperforator is at times a serious defoliator of cotton in certain areas of southern California and Arizona. It is controlled with methomyl (spray or dust) at 0.45 to 0.67 pound per acre (Technical material). Repeat applicaitons may be necessary. Sprays are more effective than dusts. Avoid the use of organophosphorus compounds during early season to protect beneficial insects. Aldicarb is effective when applied as a sidedressing between first squaring and early bloom at 2.0 pounds per acre.

Cotton Leafworm, *Alabama argillacea* (Hübner)

The following insecticides will control the cotton leafworm at the indicated dosages of technical material:

Spray	Pounds (AI) per acre
Azinphosmethyl	0.25-0.37
Carbaryl	0.5-2.0
EPN + methyl parathion	0.25-0.5+0.25-0.5
Malathion	0.4-1.25
Methyl parathion	0.25-0.5
Parathion (ethyl)	0.12-0.25
Toxaphene	2.0-4.0

Cutworms

Several species of cutworms, including the following, may develop in weeds or crops, especially legumes, and then attack adjacent cotton or cotton planted on land previously in weeds or legumes:

Black cutworm, *Agrotis ipsilon* (Hufnagel)
Palesided cutworm, *A. malefida* Guenée
Variegated cutworm, *Peridroma saucia* (Hübner)
Granulate cutworm, *Feltia subterranea* (F.)
Army cutworm, *Euxoa auxiliaris* (Grote)

Recommended control measures include thorough seedbed preparation, elimination of weed host plants, and the use of insecticides. In western areas, irrigation forces the subterranean forms to the surface where they may be treated with insecticides or destroyed by natural factors. If the vegetation in an infested area is destroyed by tillage 3 to 6 weeks before the cotton crop is seeded, an insecticide may not be needed. The following insecticides will control one or more species of cutworms at the indicated dosages of technical material:

Spray	Pounds (AI) per acre
Acephate	1.0
Carbaryl	1.5-2.0
Chlorpyrifos	0.5-1.0
Sulprofos	0.75-1.5
Toxaphene	2.0-4.0
Toxaphene + methyl parathion	2.0+1.0
Trichlorfon	0.5-1.5

Baits containing toxaphene at 2 to 4 pounds per acre, carbaryl at 1.5 pounds per acre, and trichlorfon at 1.5 pounds per acre have been satisfactory. Baits are frequently more effective than sprays or dusts against some species of cutworms.

Darkling Ground Beetles, Blapstinus spp. and Ulus spp.

Darkling ground beetles, the adults of false wireworms, occasionally affect the stand of young cotton in the western areas. Adults on young plants may be controlled with carbaryl in a bait at 1.5 pounds per acre.

Fall Armyworm, Spodoptera frugiperda (J. E. Smith)

The fall armyworm occasionally occurs in sufficient numbers to damage cotton. In 1977 infestations of the fall armyworm, which attacked squares and bolls as well as foliage, were more general than in many years. Heavy yield loss was experienced statewide in Alabama. The following insecticides will control it at the indicated dosages of technical material:

Spray	Pounds (AI) per acre
Acephate	1.0
Carbaryl	1.0-2.0
Methomyl	0.3-0.67
Methyl parathion	0.25-1.50
Monocrotophos	0.5-1.0
Sulprofos	0.75-1.5
Toxaphene	2.0-3.0
Trichlorfon	0.5-1.0

The results obtained from these materials have varied in different States; therefore, local recommendations should be followed. (See "Bollworm, *Heliothis zea* (Boddie), and Tobacco Budworm, *H. virescens* (F.)" in this section.)

Garden Webworm, Achyra rantalis (Guenée)

The garden webworm may be controlled with the following insecticides at the dosages indicated:

Spray	Pounds (AI) per acre
Carbaryl	1.0-2.0
Malathion	1.0-2.0
Methyl parathion	0.25-0.5
Toxaphene	1.5-4.0

Grasshoppers

Several species of grasshoppers, including the following, sometimes attack cotton:

American grasshopper, *Schistocerca americana* (Drury)
Trimerotropis pallidipennis pallidipennis (Burmeister)
Differential grasshopper, *Melanoplus differentialis* (Thomas)
Lubber grasshopper, *Brachystola magna* (Girard)
Migratory grasshopper, *M. sanguinipes* (F.)
Redlegged grasshopper, *M. femurrubrum* (De Geer)
Twostriped grasshopper, *M. bivittatus* (Say)

The American grasshopper overwinters as an adult and in the spring deposits eggs in the fields. Other species of grasshoppers overwinter as eggs in untilled soil, fence rows, sod waterways, around stumps, and similar locations. The species overwintering in the egg stage can be controlled best with early treatment of hatching beds before the grasshoppers migrate into the fields. Sprays or dusts have largely replaced poison baits, particularly where grasshoppers must be controlled on lush or dense vegetation. Dosages of technical material suggested to control grasshoppers on cotton come within the following ranges:

Spray	Pounds (AI) per acre
Carbaryl	1.0-2.0
Malathion	1.0-2.0
Methyl parathion	0.25-0.5
Toxaphene	2.0-4.0

The lowest dosages are effective against newly hatched to half-grown grasshoppers. The dosages should be increased as the grasshoppers mature or when the material is applied on partly defoliated plants or on plants unpalatable to the insects.

Lygus Bugs and Other Mirids

Several species of lygus bugs and other mirids, including those listed below, often are serious pests of cotton. (See "Cotton Fleahopper, *Pseudatomoscelis seriatus* (Reuter)" in this section.)

A plant bug, *Lygus hesperus* Knight
Clouded plant bug, *Neurocolpus nubilus* (Say)
Ragweed plant bug, *Chlamydatus associatus* (Uhler)
Rapid plant bug, *Adelphocoris rapidus* (Say)
Superb plant bug, *A. superbus* (Uhler)
Tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois)

The mirids *Creontiades debilis* Van Duzee, *Reuteroscopus ornatus* (Reuter), *R. sulphureus* (Reuter), and *Paraxentus guttulatus* (Uhler) also damage cotton. *C. rubrinervis* (Stal.) infested cotton in the lower Rio Grande Valley of Texas in 1974, 1975, and 1976. These insects cause damage to squares, blooms, and small bolls of cotton and constitute a major problem, particularly in the vicinity of alfalfa fields in the irrigated areas of the West. The following insecticides will control lygus bugs and other mirids at the indicated dosages of technical material:

Spray	Pounds (AI) per acre
Acephate	0.12-1.0
Azinphosmethyl	0.125-0.25
Carbaryl	0.6-2.0
Chlorpyrifos	0.2
Dicrotophos	0.1-0.5
Dimethoate	0.1-0.25
Malathion	0.7-1.25
Methyl parathion	0.12-1.0
Monocrotophos	0.1-0.5
Toxaphene	1.0-4.0
Trichlorfon	0.25-1.5

Aldicarb is effective when used as an in-furrow granule application at planting at 0.6 to 1 pound per acre.

Pink Bollworm, Pectinophora gossypiella (Saunders)

The pink bollworm occurs on the North American continent in Texas, California, Nevada, Oklahoma, New Mexico, Arizona, Arkansas, and Louisiana. It occurs in wild cotton in southern Florida. Although it also occurs in most of Mexico, it was found for the first time in 1965 in limited areas of the previously uninfested States of Sonora and Baja California. Quarantine regulations, the application of chemical controls, and cultural control requirements have made it possible to prevent economic damage in most years in the infested areas of the United States and to retard or prevent its spread to new areas. However, in recent years injurious infestations have occurred in the Imperial and Coachella Valleys of California and in Arizona.

Quarantine requirements.--The areas presently under regulation in the United States are shown in figure 1. The regulations, in general, require that all cotton or other designated articles moved from the regulated areas be treated to free them of any living pink bollworms before movement to free areas. All cottonseed must be treated before being shipped from a regulated area. Copies of the State and Federal regulations may be obtained from the regulatory agencies of the affected States or from the Plant Protection and Quarantine Programs field offices.

Cultural Control.--Approved cultural practices, effective and economical means of controlling the pink bollworm when properly carried out, greatly reduce the overwintering population. The pink bollworm hibernates in waste cotton left in the field, along roadsides, and at the gin; therefore, destruction of this material aids considerably in the control of this pest. Mandatory cultural control zones are in effect in the United States in the southern, central, and eastern section of Texas, and in regulated areas of Arkansas, Louisiana, Arizona, and California. Cultural practices used in pink bollworm control are effective in reducing the boll weevil carryover for the next year. Recommended control practices include the following:

1. Shorten the planting period and plant at the optimum time for a given locality. Use seeds of an early-maturing variety which have been culled, treated with a fungicide, and tested for germination.
2. Leave as thick a stand as has been recommended for the particular area and type of soil.
3. Produce the cotton in the shortest practicable time. Early-season control of certain insects has proved advantageous in some States but not in others. Practice early-season control where recommended by controlling cotton aphids, boll weevils, cotton fleahoppers, cutworms, thrips, and any other insects that may retard the growth and fruiting of young plants. Protection of early fruit will assure an early harvest.
4. Withhold late irrigation, and use defoliants or dessicants to hasten the opening of the bolls when the crop is mature.
5. Harvest cleanly; in areas where spindle pickers are used, final scrapping with a stripper is desirable. Use a cotton gleaner if appreciable cotton is left on the ground after harvest.

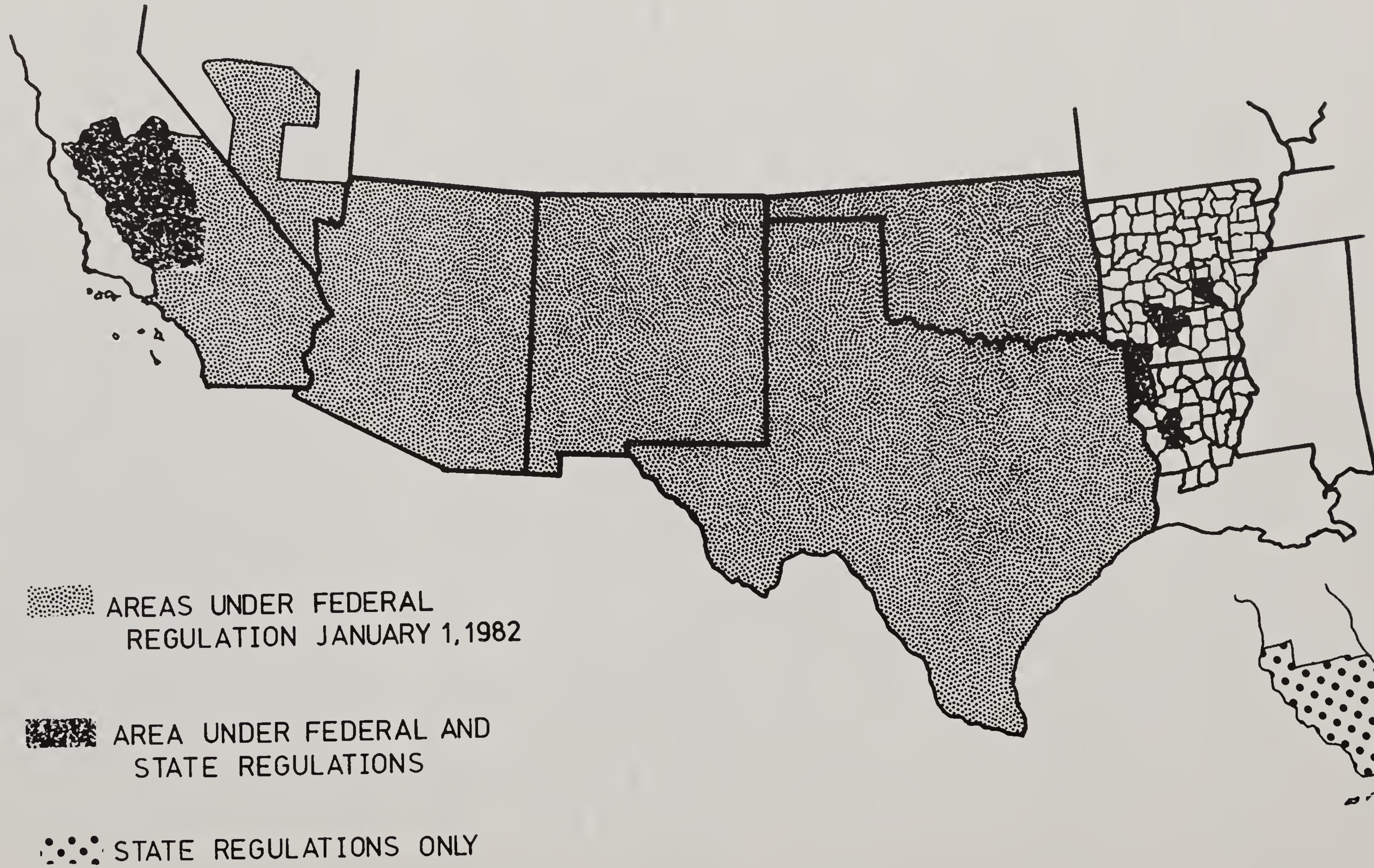

Figure 1.--Areas of the United States where the pink bollworm is presently under Federal or State regulation

6. Shred and plow under cotton stalks and debris as soon as possible after harvest. Okra stalks and debris should be shredded and plowed under at the same time because this plant is a preferred secondary host.

7. In cold areas where winter irrigation is not feasible, leave stalks standing until lowest temperatures have occurred. This is to secure a maximum kill of pink bollworms in the bolls on the stalks. However, if a large amount of crop debris, such as seed cotton or locks, is on the soil surface, a high survival of the pest may result. When this condition exists, the stalks should be shredded and plowed under as early and as deeply as possible.

8. In warmer areas the growing of volunteer and stub cotton should not be practiced.

The flail shredder is recommended over the horizontal rotary shredder for pink bollworm control. The flail shredder will kill about 85 percent of the pink bollworms left in the field after harvest, compared with 55 percent for the horizontal rotary shredder. The residue should be plowed under as deep as possible. Pink bollworm winter survival is highest in bolls on the soil surface and is six times as high in bolls buried only 2 inches deep as compared with bolls buried 6 inches deep. Before fruiting, all sprout and seedling cotton and okra developing after plowing should be destroyed to create a host-free period between crops. In arid areas, if the crop debris is plowed under in the late fall or early winter, the fields should be winter-irrigated to increase pink bollworm mortality.

Control with insecticides.--Where infestations are heavy, crop losses from pink bollworm can be reduced by proper use of insecticides. One-half to 1 pound of azinphosmethyl per acre, 0.05 to 0.1 pound of fenvalerate per acre, 0.6 to 1 pound of monocrotophos per acre, 0.1 to 0.2 pound of permethrin per acre, or 1.5 to 2.5 pounds of carbaryl per acre will control the pink bollworm. Monocrotophos, fenvalerate, permethrin, or carbaryl at the above dosages will control the boll weevil and bollworm. The use of certain insecticides for control of other cotton insects exerts a repressive effect on pink bollworm populations.

Saltmarsh Caterpillar and Other Arctiids

The saltmarsh caterpillar, *Estigmene acrea* (Drury), is a late-season pest of cotton principally in western irrigated areas. It may be controlled with the following insecticides at the indicated dosages of technical material:

Spray	Pounds (AI) per acre
Carbaryl	2.0
Methyl parathion	1.0
Trichlorfon	1.5

Occasionally, the yellow woollybear, *Diacrisia virginica* (F.), and the hairy larvae of several other tiger moths (Arctiidae), including *Callarctia phyllira* (Drury), *C. arge* (Drury), and *C. oithona* Strk., cause serious damage to cotton. Information is needed on their seasonal host plants, distribution, natural enemies, causes of serious outbreaks in cottonfields, life history, and control. (Determinations of species by specialists should always be obtained.)

Seedcorn Maggot, Hylemya platura (Meigen)

The seedcorn maggot may seriously affect the stand of cotton, particularly when planting closely follows the turning under of a green-manure crop or other heavy growth. This insect may be controlled with 2 ounces of endrin mixed with a normally used fungicide and applied onto each 100 pounds of planting seed in a slurry. Seed should be treated immediately before planting.

Spider Mites

The following spider mites are known to attack cotton:

Carmine spider mite, *Tetranychus cinnabarinus* (Boisduval)
Desert spider mite, *T. desertorum* Banks
Fourspotted spider mite, *T. canadensis* McGregor
Pacific spider mite, *T. pacificus* McGregor
Schoene spider mite, *T. schoenei* McGregor
Strawberry spider mite, *T. turkestani* Ugarov and Nikolski
Tumid spider mite, *T. tumidus* Banks
Twospotted spider mite, *T. urticae* Koch and *T. ludeni* Zacker
T. yustis McGregor

The species differ in their effect on the cotton plant and in their reaction to miticides. Accurate identification of the species is essential. The use of organic insecticides for cotton-insect control has been a factor in increasing the importance of spider mites as pests of cotton. Table 5 lists the species of spider mites and the miticides that have been found to be effective in their control. For the control of some species and suppression of others, at least 40 percent sulfur may be incorporated in dusts. Elemental sulfur cannot be incorporated in sprays applied at low gallonage, but other miticides may be substituted. Sulfur dust is more effective when finely ground and when applied at temperatures above 90°F; thorough coverage is essential. Some difficulty in the control of spider mites has been experienced with ultra-low-volume applications of recommended miticides, probably because of insufficient plant coverage.

Table 5.--Recommended dosages of miticides for control of specific species of spider mites

[Pounds (AI) per acre]

Miticide	Species								
	Carmine	Desert	*T. yustis*	Pacific	Schoene	Strawberry	Tumid	Twospotted	Ludeni
Aldicarb1/	0.3-1.0	0.6-1.0	0.6-1.0	--	--	0.6-1.0	--	0.3-1.0	--
Carbophenothion	0.25-0.75	0.375-0.5	--	--	0.25-0.5	0.375	--	0.25-0.75	--
Chlorpyrifos	1.0	0.25-1.0	--	--	--	0.25-1.0	1.0	0.25-1.0	--
Demeton	--	0.25-0.375	0.375	0.375	0.375	0.375	0.375	0.25-0.375	0.375
Dicofol	--	0.8-1.6	--	0.8-1.0	--	0.8-1.6	--	0.8-1.6	--
Dicrotophos	0.25-0.5	0.25-0.5	0.25-0.5	--	--	0.25-0.5	--	0.25-0.5	--
Disulfoton2/	0.5-1.0	0.5-1.0	--	--	--	0.5-1.0	--	0.5-1.0	--
Ethion	0.25-1.5	0.25-0.75	0.25-1.0	--	0.25-1.0	0.25-0.1	--	0.25-1.5	--
Methamidophos	0.5-1.0	--	--	--	--	--	0.5-1.0	0.5-1.0	--
Methidathion	1.0	1.0	1.0	1.0	1.0	1.0	--	0.5-1.0	--
Methyl parathion	--	0.6	--	--	0.6	--	0.6	0.6	--
Monocrotophos	0.2-1.0	0.25-1.0	0.5-1.0	0.5-1.0	0.5-1.0	0.5-1.0	0.2-1.0	0.2-1.0	0.5-1.0
Oxydemeton-methyl	0.25-0.5	0.25-0.5	0.25-0.5	0.25-0.5	0.25-0.5	0.25-0.5	0.2-0.5	0.25-0.37	0.25-0.5
Parathion	--	0.25-0.5	0.1-0.2	--	--	--	0.25-0.5	0.125-1.0	0.2
Phorate3/	0.5-1.5	0.5-1.5	--	--	--	0.5-1.5	--	0.5-1.5	--
Propargite	1.25	--	--	0.8-1.6	--	0.8-1.6	--	0.5-1.6	--
Sulfur	--	25-30	--	--	--	25-35	--	20-50	--

1/ In-furrow granule treatment at planting.
2/ In-furrow granule treatment at planting or 0.5 pound per hundredweight of planting seed.
3/ In-furrow granule treatment at planting or 1.3 to 1.5 pounds per hundredweight of planting seed.

Stink Bugs

The following stink bugs are sometimes serious pests of cotton:

Brown stink bug, *Euschistus servus* (Say)
Conchuela, *Chlorochroa ligata* (Say)
Dusky stink bug, *E. tristigmus* (Say) and *E. conspersus* (Uhler)
Green stink bug, *Acrosternum hilare* (Say)
Onespot stink bug, *E. variolarius* (Polisat de Beauvois)
Redshouldered plant bug, *Thyanta custator* (F.);
T. rugulosa (Say); *T. pallidovirens spinosa* (Ruckers)
Say stink bug, *Chlorochroa sayi* Stal
Southern green stink bug, *Nezara viridula* (L.)
Western brown stink bug, *Euschistus impictiventris* Stal

The importance of these pests and the species involved vary from year to year and from area to area. The damage is principally confined to the bolls and results in reduced yields and lower quality of both lint and seed. The following insecticides applied at the indicated dosages of technical material have given control of one or more species of stink bugs:

Spray	Pounds (AI) per acre
Carbaryl	2.0
Endosulfan	1.0
Methyl parathion	0.75-1.5
Parathion (ethyl)	0.5-1.0
Trichlorfon	1.0-1.5

Thrips

Thirps often injure cotton seedlings, especially in areas where vegetables, legumes, and small grains are grown extensively. The following species have been reported to cause injury:

Flower thrips, *Frankliniella tritici* (Fitch);
(*F. exigua* Hood; *F. gossypiana* Hood; and *F. occidentalis* (Pergande)
Onion thrips, *Thrips tabaci* Lindeman
Sericothrips variabilis (Beach)
Tobacco thrips, *F. fusca* (Hinds)

In some areas cotton seedlings usually recover from thrips injury; therefore, control is not recommended unless the stand is threatened. In other areas damage by thrips is more severe and control measures are generally recommended. Injury from thrips alone, or the combined injury of thrips and disease, may reduce or even destroy stands of young plants. A heavy infestation may retard plant growth and delay fruiting and crop maturity. Although thrips are predominantly pests of seedlings, damaging infestations sometimes occur on older cotton in certain areas. The following insecticides at the indicated dosages of technical material are recommended, when the situation warrants their use:

Spray	Pounds (AI) per acre
Azinphosmethyl	0.08-0.2
Carbaryl	0.5-0.85
Dicrotophos	0.1-0.2
Dimethoate	0.1-0.25
Endosulfon	0.3-0.75
Malathion	0.25-1.3
Methamidophos	1.0
Methyl parathion	0.12-0.5
Monocrotophos	0.1-0.2
Parathion	0.5
Toxaphene	1.20
Trichlorfon	0.25

The following materials are effective when used as seed treatments or as in-furrow granule applications at planting at the indicated dosages of technical material:

Insecticide	Pounds per acre	Pounds per hundredweight of cottonseed
Acephate	-----	0.5
Aldicarb	0.3-0.5	-----
Disulfoton	0.6-1.0	0.25-0.5
Monocrotophos	-----	0.25-1.25
Phenamiphos	1.6-3.3	-----
Phorate	0.5-1.5	1.30-1.5

The bean thrips, *Caliothrips fasciatus* (Pergande), is an occasional mid- to late-season pest of cotton in parts of California. Toxaphene at 2 to 3 pounds per acre gives satisfactory control when applied in either a spray or dust. *Caliothrips phaseoli* (Hood) damaged cotton near Bard, Imperial County, Calif., in 1962. *Scirtothrips* sp. causes severe crinkling of the top leaves of cotton in localized areas of Arizona, Mississippi, and Texas. *Kurtomathrips morrilli* Moulton was described in 1927 from specimens taken on cotton at Gila Bend, Ariz. It was collected from cotton at Seeley, Calif., in May 1930 and at Laveen, Ariz., in July, 1943 and was reported to have caused severe injury to cotton at Gila Bend in July 1957. *Frankliniella occidentalis* and *F. gossypiana* rarely occur on cotton in the Eastern United States. *F. occidentalis* was reported in Georgia damaging cotton in 1980-81. In the West, *F. tritici* is of little importance on cotton, and *F. fusca* does not occur.

Whiteflies

The bandedwing whitefly, *Trialeurodes abutilonea* (Haldeman), the greenhouse whitefly, *T. vaporariorum* (Westwood), and the sweetpotato whitefly, *Bemisia tabaci* (Gennadius), are usually kept in check by parasites and diseases, but occasionally may be serious pests late in the season. *Bemisia tabaci* is reported to be a vector of the leaf crumple virus of cotton. The bandedwing whitefly has been a problem in Louisiana since 1964, and infestations have increased in Mississippi, Alabama, Arkansas, Oklahoma, and Georgia since 1972. The bandedwing whitefly may be controlled with monocrotophos spray at 0.25 to 1.0 pound per acre, with methamidophos at 0.2 to 0.25 pound per acre, with acephate at 0.5 to 1 pound per acre, and with methidathion at 0.25 to 0.5 pound per acre.

Whitefringed Beetles, *Graphognathus* spp.

Whitefringed beetles are pests of cotton and many other farm crops in limited areas of Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, and Tennessee. Infestations in recent years have been discovered in Maryland, Virginia, and Texas. The larvae feed on the roots of young plants. When applied to the foliage as recommended for the control of cotton insects, toxaphene will reduce adult populations; however, the principal benefit is the reduction of subsequent larval populations.

Wireworms

Several species of wireworms are associated with cotton. Damage is caused by the sand wireworm, *Horistonotus uhlerii* Horn, in South Carolina and Louisiana, by *Melanotus* spp. in Louisiana and Mississippi, and by the Pacific Coast wireworm, *Limonius canus* LeConte, in California. Adults of the tobacco wireworm (or spotted click beetle), *Conoderus vespertinus* (F.), are frequently found on the cotton plant, and the larvae caused damage to cotton in Louisiana in 1981. Wireworms, together with false wireworms and the seedcorn maggot, sometimes prevent the establishment of a stand. To control these insects, treat the seed with 2 ounces of endrin plus a normally used fungicide per 100 pounds in a slurry. Approved crop-rotation practices, increased soil fertility, and added humus help to reduce damage to cotton by the sand wireworm.

Yellowstriped Armyworm, Spodoptera ornithogalli (Guenée), and Western Yellowstriped Armyworm, S. praefica (Grote)

These insects sometimes cause considerable damage to cotton. The yellowstriped armyworm is difficult to kill with insecticides. However, trichlorfon at 1.5 pounds per acre and methyl parathion at 1 to 1.5 pounds per acre give good control of large and small larvae. The western yellowstriped armyworm, which attacks cotton in California and Texas, is controlled with trichlorfon at 0.75 to 1.0 pound per acre and toxaphene at 2 to 3 pounds per acre. Migrations from surrounding crops may be stopped with barriers of 5 percent trichlorfon or 5 percent carbaryl at 2 pounds per 100 linear feet.

Miscellaneous Insects

The brown cotton leafworm, *Acontia dacia* Druce, was collected from three counties in Texas in 1953. Since then, damaging infestations have occurred in some years over wide areas of Texas and in Louisiana. Collections of this insect have been made in Arkansas. This pest may be controlled with azinphosmethyl at 0.25 pound per acre, malathion at 0.25 pound per acre, and parathion (ethyl) at 0.125 pound per acre.

Several *Anomis* leafworms occur in the cotton-growing regions of Africa; Asia; Australia; North, Central, and South America; and the East and West Indies. Three species--*A. erosa* Hübner, *A. flava fimbriago* (Stephens), and *A. texana* Riley--occasionally damage cotton in the United States. They are often mistaken for the cotton leafworm and are sometimes found on the same plants with it. Although specific control data are lacking, the insecticides recommended for control of the cotton leafworm might also be effective against *Anomis* leafworms.

Root aphids known to attack cotton are the corn root aphid, *Aphis maidiracidis* Forbes; *Smynthurodes betae* (Westwood); and *Rhopalosiphum rufiabdominalis* (Sasaki). So far as is known, injury before 1956 was confined to the eastern seaboard. *S. betae* destroyed spots of cotton up to 1-1/2 acres in fields in Pemiscot County, Mo., in 1956. In 1961, root aphids caused some damage to cotton in the northeastern counties of North Carolina and Arkansas. In 1975, *S. betae* killed 20 percent of the stand of seedling cotton at Roswell, Chaves County, N. Mex., a new State record. Several species of ants are known to be associated with root aphids, the principal one being the cornfield ant, *Lasius alienus* (Foerster). Chemical control of root aphids has been directed at this ant. Some new materials are effective as soil insecticides and might be tested against root aphids attacking cotton. Root aphids injure cotton chiefly in the seedling stage. Since cotton in this stage shows injury without any evidence of insects being present, the underground parts should be examined carefully. Ant mounds at the base of these plants indicate the presence of root aphids.

The cowpea aphid, *Aphis craccivora* Koch, the green peach aphid, *Myzus persicae* (Sulzer), and the potato aphid, *Macrosiphum euphorbiae* (Thomas), are common on seedling cotton. Cotton is not believed to be a true host of these species. In 1963, *A. craccivora* caused severe and permanent stunting of cotton plants in the San Joaquin Valley of California.

The garden springtail, *Bourletiella hortensis* (Fitch), has caused injury to cotton locally in Hertford County, N. C. Another springtail,

Entomobrya unostrigata Stach, has occasionally damaged seedling cotton over a wide area of the southern High Plains of Texas and New Mexico.

The corn silk beetle, Calomicrus brunneus (Crotch), has been a pest of cotton in localized areas of South Carolina, Georgia, Alabama, Mississippi, and Louisiana, but little is known about it.

Leaf beetles of the genus Colaspis are widespread and often found on cotton, frequently on the foliage or near the base of squares and bolls where they usually feed on the surrounding bracts.

The cowpea curculio, Chalcodermus aeneus Boheman, sometimes causes damage to seedling cotton.

A curculionid, Compsus auricephalus (Say), damaged young cotton plants and foliage in Grady County, Okla., in 1961. It also appeared in large numbers in cottonfields in Pope County, Ark. In 1963, heavy populations caused considerable foliage damage to young plants in localized areas of Grimes, Robertson, and Brazos Counties in Texas and in Obion and Lake Counties in Tennessee. A curculionid, Conotrachelus erinaceus LeConte, caused damage to stems of seedling cotton in isolated instances in Marion County, Ala., in 1962. A curculinoid, Otiorhynchus cribricollis Gyllenhal, caused spotted heavy damage to cotyledons of seedling cotton in New Mexico in 1967 and 1972.

First generation adults of the spotted cucumber beetle, Diabrotica undecimpunctata howardi Barber, were heavier than usual on several crops, including cotton in western Tennessee, in July 1973. Some light damage is usually expected on all infested crops except cotton. However in 1973 the pests were numerous enough to cause light to moderate damage to squares and blooms. Adults feed in the ovary of the bloom, resulting in loss of the young boll. Some feeding on squares was noted in all fields surveyed, but damage was light.

The cotton stainer, Dysdercus suturellus (Herrich-Schaffer), is found within the United States in Florida only. However, probably owing to mistaken identity, its presence has also been recorded in Alabama, Georgia and South Carolina. No work on control has been formally reported in recent years, but observations indicate that dusts containing 10 percent toxaphene will control insects of this genus.

Several leafhoppers of the genus Empoasca are often abundant on cotton in many sections of the Cotton Belt. Serious injury has been reported only in California, however, and this was caused by two species, the southern garden leafhopper, E. solana DeLong, and the potato leafhopper, E. fabae (Harris). These species are known to be phloem feeders on some crops and cause damage typical of this type of feeding on cotton. Sprays of trichlorfon at 1 pound per acre, malathion at 1 pound per acre, parathion at 0.5 pound per acre, or demeton at 0.25 pound per acre have given satisfactory control.

The striped blister beetle, Epicauta vittata (F.), sometimes causes severe foliage damage in small localized areas. Damage usually results when weeds, which are preferred host plants, are cleaned out of cotton. Total loss of foliage may result in small areas before the insects move out of the field. Spot treatment with the organochlorines is usually effective for control of outbreaks.

Field crickets, Gryllus spp., occasionally feed on cotton bolls and young plants in California, Arizona, and Arkansas. During periods of drought late in the season, they may feed on the seed of open bolls, es-

pecially in the Delta sections of Arkansas, Louisiana, and Mississippi. This feeding is usually done at night, since crickets hide during the day in deep cracks in the soil. Crickets may be controlled with 5 percent carbaryl or trichlorfon bait at 30 pounds per acre.

The whitelined sphinx, *Hyles lineata* (F.), occasionally occurs in large numbers in uncultivated areas and migrates to cotton. It may be controlled on cotton with sprays of carbaryl at 1.5 to 2.0, trichlorfon at 0.5 to 1.0 or toxaphene at 2 to 3 pounds per acre. Migrations may be stopped with barrier strips of 20 percent toxaphene or with physical barriers.

Serpentine leafminers, *Liriomyza* spp., and *L. pictella* (Thomson) have been present in large numbers in some areas of California during the last few years. Drought conditions favor infestations of these pests. Heavy infestations may result in considerable shredding of leaves. Infestations are brought under control by rain or irrigation. Field tests at Waco, Tex., showed that the best reductions were obtained with parathion at 1.0 pound per acre. Seed treatment of phorate at 0.25 to 0.5 pound per acre and disulfoton at 1 pound per acre are also effective 4 to 6 weeks after planting.

Damage to cotton by periodical cicadas, *Magicicada* spp., in the United States was first reported in 1905. Damage is caused by the deposition of eggs in the stems of young plants, branches of older plants, and occasionally in leaf petioles. The parts of the plant above the oviposition puncture usually die. Growth below the puncture results in low, bushy plants. Severe local damage to cotton by *Diceroprocta vitripennis* (Say) occurred in the river bottoms of nine counties in Arkansas in 1937. A cicada, undetermined species, caused light damage to cotton in some areas in Maricopa County, Ariz., in 1961.

The harlequin bug, *Murgantia histrionica* (Hahn), heavily infested a few cottonfields in Graham County, Ariz., in August 1959. Its feeding habits there were similar to those of other stink bugs. No immature stages were noted.

The barberpole caterpillar, *Mimoschima rufofascialis* (Stephens), a pyralid larva, occasionally attacks cotton bolls in the Imperial and San Joaquin Valleys of California. It also has been reported from Arizona, Oklahoma, and Texas.

Bugs of the genus *Nysius*, *N. ericae* (Schilling), *Xyonysius californicus* Stal, and *N. raphanus* Howard, commonly called false chinch bugs, frequently migrate to cotton from adjacent weed hosts. Stands of seedling cotton may be destroyed by adults and nymphs. Methyl parathion and parathion (ethyl) are effective at 0.5 pound per acre.

Tree cricket, *Oecanthus* spp., infestations caused alarm to some southwestern Oklahoma cottongrowers in mid-July 1958. Approximately 3-percent lodging occurred in the Blair area. There is evidence that this group of insects may be predaceous on aphids.

The European corn borer, *Ostrinia nubilalis* (Hübne), was first reported on cotton in the United States during 1955. The first report came from Franklin County, Tenn., where a few plants near the edge of a field were severely damaged. This was in July in a 3-acre field adjacent to one that was in corn the previous year. The cotton was only 8 to 10 inches high, and the larvae had entered the stems 2 to 6 inches from the ground and burrowed up through their centers. In August light infestations occurred in cotton in Dunklin, New Madrid, Pemiscot, Butler, Stoddard, and Mississippi

Counties in Missouri and in Madison County, Tenn. The borers were found boring into the upper third of the stems, and second- and third-instar larvae were attacking small bolls. These records are of special interest because the European corn borer is apparently spreading in the Cotton Belt. No reports of this insect on cotton were received during 1956-57. In 1958 it was found boring in cotton stalks in Autauga and Madison Counties, Ala., and in Washington County, Miss., in late July. In 1959 as many as 10 percent of the plants were infested in a 10-acre field of cotton in Etowah County, Ala.; the field had been planted to corn in 1958. It was also found in Madison Parish, La., in 1959. Damage was confined to the terminal 6 to 8 inches of the plant. Other infestations occurred in cottonfields in Autauga, Ala. In 1961 larvae were found in cotton in Hardeman, Lincoln, and Fayette Counties in southern Tennessee. In 1966 larvae were found in cotton in Florence, S.C., and in 1979 they caused yield loss extimated at 20 percent in one field with light damage in other fields. The European corn borer caused minor damage in isolated fields in Florida in 1980-81. In South Carolina it damaged 5 to 15 percent of cotton stems in 1979 and 1981. There was a 20 percent yield loss in one field in 1980. In other parts of the world, particularly in Russia, Turkistan, and Hungary, it was a serious pest of cotton. One reference states, "In Turkistan it is principally cotton which is attacked by the larvae and in which they bore long tunnels in the upper part of the stem." Entomologists and other interested persons throughout the Cotton Belt should be on the alert to detect its presence and, whenever possible, record the type and degree of injury, seasonal and geographical distribution, and control measures that might be of value.

The Fuller rose beetle, Pantomorus cervinus (Boheman), is occasionally a pest of cotton. It is a leaf feeder and usually attacks cotton in the early season, causing ragging of the leaves and partial defoliation. It over winters as an adult in about the same habitat as the boll weevil. Examinations of woods surface trash for hibernating boll weevils often reveal specimens of the Fuller rose beetle. Its presence in cotton has been reported from Georgia more frequently than from any other area.

The stalk borer, Papaipema nebris (Guenée), is widely distributed east of the Rocky Mountains. It attacks many kinds of plants, including cotton, and is so destructive that one borer in a field may attract attention. The borers are most likely to be seen near the edges of cottonfields. Light marginal injury occurred in scattered fields in Missouri during June 1957. It also caused some injury to cotton in Mississippi and Tennessee in 1956. In 1961 it caused some damage along the edges of many cottonfields in western and southern counties in Tennessee. It is sometimes mistaken for the European corn borer. Clean cultivation and the keeping down of weed growth help to hold them in check. The use of stalk shredders early in the fall should reduce their numbers.

The white grub, Phyllophaga ephilida (Say), destroyed 5 acres of cotton in Union County, N.C., during 1956. As many as 20 larvae per square foot were found. P. zavalana Reinhard is a pest of cotton in the Matamoras area of Mexico, where the adults feed on foliage, particularly in the seedling stage. It is known to occur in Zavala and Dimmit Counties in Texas. P. cribrosa (LeConte), sometimes known as the "4 o'clock bug" in west Texas, has also been feeding on young cotton in that area. Moderate damage was caused to young cotton plants in the Arkansas Delta area in 1962 by larvae of P. implicita (Horn).

The cotton stem moth, Platyedra subcinerea (Haworth), a close relative of the pink bollworm, was first discovered in the United States in 1951, when larvae were found feeding in hollyhock seed in Mineola, Long Island, N.Y. It is a pest of cotton in Iran, Iraq, Morocco, Turkistan, and the U.S.S.R. and feeds on hollyhock and other malvaceous plants in England, France, and central and southern Europe. Collections made in 1953 extended its known distribution in this country to a large part of Long Island and limited areas in Connecticut and Massachusetts. Extensive scouting during 1954 disclosed that it had reached 11 counties in 4 States as follows: Hartford and New Haven, Conn.; Essex and Plymouth, Mass.; Monmouth, Ocean, and Union, N.J.; Westchester and all counties of Long Island (Nassau, Queens, and Suffolk), N.Y. There had been no reported spread since 1954, until 1965, when its presence was reported in Rockingham County, N.H. Although this species has not been found in the Cotton Belt in the United States, it is desirable to keep on the lookout for it on cotton, hollyhock, and other malvaceous plants. In 1956 it was collected from a natural infestation on cotton growing on the laboratory grounds at Farmingdale, N.Y.

Heavy feeding on cotton by the Japanese beetle, Popillia japonica Newman, was reported in Sampson County, N.C., in 1961. Adults of the Japanese beetle caused 30- to 35-percent defoliation of cotton plants in fields in the more heavily infested areas in North Carolina in 1970

A giant appletree borer, Prionus sp., caused isolated root damage to cotton in one county in Arkansas in 1962.

Several of the leaf rollers, Tortricidae, occasionally damage cotton. Platynota stultana (Walsingham) and P. rostrana (Walker) are the species most commonly recorded, but P. flavedana (Clemens) and P. idaeusalis (Walsingham) have also been reported. These species are widely distributed and have many host plants. P. stultana has at times been a serious pest of cotton in the Imperial Valley of California and parts of Arizona and New Mexico. Trichlorfon at 1 pound per acre or carbaryl at 2 pounds per acre have satisfactorily controlled the species that occur on cotton in California.

Larvae of the roughskinned cutworm, Proxenus mindara Barnes and McDonnough, cut bolls from lodged plants by feeding at the boll base in a cottonfield at Shafter, Calif., in 1964.

Adults of the buprestid beetle, Psiloptera drummondi (Laporte and Gory), occasionally cause damage to cotton. The damage consists of partly girdled terminals that break over and die.

The pink scavenger caterpillar, Sathrobrota rileyi (Walsingham), is one of several insects that resemble the pink bollworm and is sometimes mistaken for it by laymen. The larva is primarily a scavenger in cotton bolls and cornhusks that have been injured by other causes.

The cotton square borer, Strymon melinus (Hübner), occurs throughout the Cotton Belt but rarely causes economic damage. The injury it causes to squares is often attributed to the bollworm.

The palestriped flea beetle, Systena blanda Melsheimer, the elongate flea beetle, S. elongata (F.), and S. frontalis (F.) sometimes cause serious damage to seedling cotton in some areas. They can be controlled with endrin at 0.1 pound per acre and toxaphene at 2 to 3 pounds per acre. The sweetpotato flea beetle, Chaetocnema confinis Crotch, injured seedling cotton in the Piedmont section of South Carolina in May 1954. The striped flea beetle, Phyllotreta striolata (F.), damaged cotton in Alabama in 1959.

Other species of flea beetles have infested cotton, but records regarding the injury they caused are lacking. When flea beetle injury to cotton is observed, specimens should be submitted to specialists for identification, with a statement regarding the damage they caused, the locality, and the date of collection.

The greenhouse leaftier, *Udea rubigalis* (Guenee), also known as the celery leaftier, has occasionally been abundant on cotton in the San Joaquin Valley. Despite the heavy populations, damage was generally slight and restricted to foliage on the lower third of the plants in lush stands. In the few places where it was necessary to control this pest, endrin at 0.4 pound per acre in a dust or spray was effective. This pest caused damage in three fields near Yuma, Ariz., in 1964.

The false celery leaftier, *Udea profundalis* (Packard), caused considerable defoliation of cotton in some fields in Tulare, Kings, and Fresno Counties, Calif., in 1962. Control was difficult because of the insect's feeding habits on the lower part of plants within a web. Carbaryl at 2 pounds per acre or trichlorfon at 1.0 pound per acre were effective against this pest.

Damage to cotton stalks by undetermined species of termites occurred in western Tennessee in 1961 and in previous years in Texas. Termites, *Reticulitermes* sp. (family Rhinotermitidae), partly destroyed a stand of cotton in Little River County, Ark., in 1961.

Insects in Stored Cottonseed and Seed Cotton

Insect infestations in cottonseed during storage can be minimized if proper precautions are followed. Cottonseed and seed cotton should be stored only in a bin or room thoroughly cleaned of all old cottonseed, grain, hay, or other similar products in which insects that attack stored products are likely to develop. Among the insects that cause damage to stored cottonseed or to cottonseed meal are the cigarette beetle, *Lasioderma serricorne* (F.), the Mediterranean flour moth, *Anagasta kuehniella* (Zeller), the almond moth, *Cadra cautella* (Walker), and the Indian meal moth, *Plodia interpunctella* (Hübner). Other insects commonly found in cottonseed are the flat grain beetle, *Cryptolestes pusillus* (Schönherr), the red flour beetle, *Tribolium castaneum* (Herbst), and the sawtoothed grain beetle, *Oryzaephilus surinamensis* (L.). Malathion is registered as a seed treatment for cottonseed. Seed so treated should not be used for food or feed. The pink bollworm, *Pectinophora gossypiella* (Saunders), may be found in stored cottonseed, but such infestations would be present in the seed before they are stored.

INSECT IDENTIFICATION AND COTTON-INSECT SURVEYS

Prompt and accurate identification of insects and mites is a necessary service to research and to the control of cotton insects. Applied entomologists owe much to taxonomists for services often rendered on a volunteer basis. Approved common names are convenient and useful, but local or nonstandard common names create confusion. Entomologists are urged to submit common names to the ESA Committee on Common Names of Insects for consideration, where such are needed as for *Lygus hesperus*. Research in taxonomy has been productive of new developments. Major changes have been

made in the classification of spider mites that attack cotton. Several species of thrips and plant bugs have recently been added to the list of cotton pests. The Melanoplus mexicanus group of grasshoppers has been completely revised, Heliothis virescens (F.) has been accurately defined, and several scientific names have been changed.

The importance of surveys to an over'all cotton-insect control program has been clearly demonstrated. Surveys conducted on a cooperative basis by State and Federal agencies in most of the major cotton-growing States have developed into a broad, up-to-date advisory service for the guidance of county agents, ginners, farmers, and other leaders in agriculture who are interested in the distribution and severity of cotton-insect pests, as well as the industry that serves the farmers by supplying insecticides. As a result of this survey work, farmers are forewarned of the insect situation, insecticide applications are better timed, and losses are materially reduced below what they would be without the information thus gained. The surveys also help to direct insecticides to areas where supplies are critically needed.

It is recommended that cotton-insect surveys be continued on a permanent basis, that they be expanded to include all cotton-producing States, and that the survey methods be standardized. It is further recommended that the greatest possible use be made of fall, winter, and early spring surveys as an index to the potential infestation of next season's crop. Each year more people are being employed by business firms, farm operators, and others to determine cotton-insect populations. State and Federal entomologists should assist in locating and training personnel that have at least some basic knowledge of entomology. Whenever possible, voluntary cooperators should be enlisted and trained to make field observations and records and to submit reports during the active season.

Surveys to detect major insect pests in areas where they have not previously been reported may provide information that can be used in restricting their spread or in planning effective control programs. The survey methods may include (1) visual inspection, (2) using traps containing aromatic lures or sex and aggregating pheromones, (3) using light traps, (4) using mechanical devices such as gin-trash machines, (5) examination of glass windows installed in lint cleaners used in ginning, and (6) using portable vacuum devices for sampling insect populations. The methods of making uniform surveys on several of the important insects are described below. Light traps have provided valuable survey information on beet armyworms, bollworms, brown cotton leafworms, cabbage loopers, cotton leafworms, cutworms, fall armyworms, garden webworms, pink bollworms, saltmarsh caterpillars, whitelined sphinxes, yellowstriped armyworms, and yellow woollybears. Pheromone traps have provided valuable survey information on the boll weevil, bollworm, pink bollworm, tobacco budworm, cabbage looper, and fall armyworm.

Boll Weevil

Surveys to determine winter survival of the boll weevil are made in several States. Counts are made in the fall soon after the weevils have entered hibernation and again in the spring before they emerge from winter quarters. A standard sample is 2 square yards of woods surface trash taken from the edge of a field where cotton was grown in the previous season.

Three samples are taken from each of 30 locations in an area, usually consisting of three or four counties. Fall and spring catches of weevils in pheromone traps are used to supplement or replace counts from surface wood trash.

In the main boll weevil area, counts are made on seedling cotton to determine the number of weevils entering cottonfields from hibernation quarters. The number per acre is figured by examining the plants on 50 feet of row in each of five representative locations in the field and multiplying the total by 50. Additional counts are desirable in large fields.

Square examinations are made weekly after the plants are squaring freely or have produced as many as three squares per plant. While walking diagonally across the field pick 100 squares, one-third grown or larger, taking an equal number from the top, middle, and lower branches. Do not pick squares from the ground or flared or dried-up squares that are hanging on the plant. The number of squares found to be punctured is the percentage of infestation. To obtain a total of 100 to 500 squares, an alternate method is to inspect about 25 squares in each of several locations distributed over the field. The number of squares inspected depends upon the size of the field and the surrounding environment. The percentage of infestation is determined by counting the punctured squares. In both methods all squares that have egg or feeding punctures should be counted as punctured squares. Sequential sampling, also based on square inspections, requires fewer squares to be inspected in making pest management decisions at about a 90 percent level of reliability.

The point-sample method developed by Arkansas entomologists consists of the following procedures: Select a representative area in a field and mark a starting point on a row. Examine the first 50 green squares that are one-fourth inch or larger in diameter for boll weevil punctures. Count those that are punctured and step off the feet of row required for the 50 squares. Four such counts, a total of 200 squares, are adequate for uniform fields up to 40 acres in size. Fields that are larger or that are not uniform should be considered as separate fields with four counts made in each. The percentage of punctured squares, number of squares per acre, and number of punctured squares per acre can be determined from the point-sample information.

A conversion table for usual row widths in an area with various numbers of row feet, 1 to 250, required for a 200-square count is prepared for ease in determining the number of squares and punctured squares per acre. Example: If 10 feet of a 40-inch row are required for 200 squares, there are 261,000 squares per acre. If 50 percent of the squares are punctured, there are 130,500 punctured squares per acre.

Bollworm and Tobacco Budworm

Examinations for bollworm eggs and larvae should be started as soon as the cotton begins to square and repeated every 5 days, if possible, until the crop has matured. In some areas it may be necessary to make examinations for bollworm damage before cotton begins to square. While walking diagonally across the field examine the top 3 or 4 inches of the main-stem terminals, including the small squares, of 100 plants. Whole-plant examinations should be made to insure detection of activity not evident from terminal

counts. Sequential sampling, also based on terminal, square, and boll inspections, requires fewer inspections of terminals, squares, and bolls in making pest management decisions at about a 90 percent level of reliability. Eggs of cutworms, cabbage looper, and other lepidopterous species are sometimes mistaken for those of the bollworm. The percentage of damaged squares, number of squares per acre, and number of damaged squares can be determined by using the point-sample method given under "Boll Weevil" above.

Cotton Aphid

To determine early-season cotton aphid infestation, walk diagonally across the field and examine many plants; then record the degree of infestation as follows:

None, if none is observed.
Light, if aphids are found on an occasional plant.
Medium, if aphids are present on numerous plants and some of the leaves curl along the edges.
Heavy, if aphids are numerous on most of the plants and the leaves show considerable crinkling and curling.

To determine infestations on fruiting cotton, begin at the margin of the field and, while walking diagonally across it, examine 100 leaves successively from near the bottom, middle, and top of each plant. Record the degree of infestation, according to the average number of aphids estimated per leaf, as follows:

None, 0.
Light, 1 to 10.
Medium, 11 to 25.
Heavy, 26 or more.

Cotton Fleahopper

Weekly inspections should begin as soon as the cotton is old enough to produce squares. In some areas inspections should be continued until the crop is set. While walking diagonally across the field, examine 3 or 4 inches at the top of the main-stem terminals of 100 cotton plants--counting both adults and nymphs. Sequential sampling, also based on terminal inspections, requires fewer than 100 terminal inspections in making pest management decisions at about a 90 percent level of reliability. To determine populations, white or black cloth sheets are placed under the plants, which are then thoroughly shaken. Ten 3-row-foot samples are taken at random within a field. Populations are recorded on a per-acre basis.

Cotton Leafworm

The following levels of leafworm infestation, on the basis of ragging and the number of larvae per plant, are suggested for determining damage:

None, if none is observed.
Light, if 1 or only a few larvae are observed.
Medium, if 2 to 3 leaves are partly destroyed by ragging, with 2 to 5 larvae per plant.
Heavy, if ragging of leaves is extensive, with 6 or more larvae per plant, or if defoliation is complete.

Lygus Bugs and Other Mirids

Inspections should be made at 3- to 7-day intervals, beginning at pinhead square stage and continuing until early September. Infestations should be determined by making a 50- to 100-sweep count at each of four or more locations. Sweeping is accomplished by passing a 15-inch net through the tops of the plants in one row, with the lower edge of the net slightly preceding the upper edge. Contents of the net should be examined carefully to avoid over-looking very small nymphs. The plant terminal inspection, as described for the cotton fleahopper, may also be used. During hot summer weather, sweeping should not be made between 11:30 a.m. and 3:00 p.m., since lygus bugs are prone to move into plant cover to avoid heat. Population determinations are made using the cloth-sheet method described above for cotton fleahoppers. Sequential sampling, also based on terminal inspections or sweep-net counts, requires fewer terminal inspections or net sweeps in making pest management decisions at about a 90 percent level of reliability.

Pink Bollworm

Counts to determine the degree of infestation in individual fields may be made early in the season by inspecting blooms and later by inspecting bolls. Bloom inspections for comparing yearly early-season population should be made to obtain an estimate of the number of larvae per acre.

Bloom inspection.--Five days after the first bloom appears, but not later than 15 days, check for number of larvae per acre as follows: Step off 300 feet of row (100 steps), and count the rosetted blooms at five representative locations in the field (1,500 feet). Add the number of rosetted blooms from these five locations, and multiply by 10 to obtain the number of larvae per acre.

Boll inspection.--Check weekly for the percentage of bolls infested as follows: Walk diagonally across the field and collect at random 100 bolls (2/3 grown or larger). Crack each boll and examine the inside of the hull for tunnels made by young larvae. Where tunneling is not found, check lint and seed for evidence of larval feeding. Record the number of bolls infested on a percentage basis.

Other inspection techniques.--Other inspection methods, discussed below, are helpful in directing control activities against the pink bollworm. They make possible the detection of infestations in previously uninfested areas and the evaluation of increases or decreases as they occur in infested areas. They are also used to determine the population of larvae in hibernation and their carryover to infest the new cotton crop.

1. Inspection of lint cleaner: During the ginning process the free larvae remaining in the lint are separated in the lint cleaners, and a substantial number of them are thrown and stuck on the glass inspection

plates; all these larvae are dead. For constant examination at a single gin, wipe off the plates and examine after each bale is ginned. In this way the individual field that is infested may be determined. For general survey, make periodic examinations to detect the presence of the pink bollworm in a general area.

2. Examination of debris: Between January and the time squares begin to form in the new crop, examine old bolls or parts of bolls from the soil surface in known infested fields. Examine the cotton debris from 50 feet of row at five representative points in the field for the number of living pink bollworms. Multiply by 50 to determine the number of living larvae per acre. Such records, when maintained from year to year, provide comparative data that may be used in determining appropriate control measures.

3. Use of sex lure traps: Traps containing a sex attractant extracted from the tips of the abdomens of female pink bollworm moths were highly effective in trapping male moths. This method was replaced by a synthetic attractant, hexalure, which was effectively used for both detection of infestations and for timing the application of insecticides for control of the pest. This method of control resulted in a substantial financial savings to growers. Recently, the true sex attractant, gossyplure, has been synthesized and is now being used in detection and in research as a male confusant in the control of the pink bollworm as well as in early-season mass-trapping programs. Gossyplure has proven to be more efficient in both detection and in the timing of insecticide applications in some areas.

Spider Mites

Examine 25 or more leaves from representative areas within a field taken successively from near the bottom, middle, and top of each plant. Record, according to the average number of mites per leaf, the degree of infestation as follows:

None, 0.
Light, 1 to 10.
Medium, 11 to 25.
Heavy, 26 or more.

Thrips

While walking diagonally across the field, examine the plants and record the damage as follows:

None, if no thrips or damage are found.
Light, if newest unfolding leaves show only a slight brownish tinge along the edges, with no silvering of the underside of these or older leaves, and only an occasional thrips is seen.
Medium, if newest leaves show considerable browning along the edges and some silvering on the underside of most leaves, and thrips are found readily.
Heavy, if silvering of leaves is readily noticeable, terminal buds show injury, general appearance of plants is ragged and deformed, and thrips are numerous.

Plants beaten over a thrips box or over a piece of cloth may be used to determine the numbers of thrips per plant. Use of sequential sampling will usually reduce the number of plants needed to determine population levels with no loss in accuracy.

Predators

Populations of predators may be estimated by counting those seen while examining leaves, terminals, and squares for pest insects. When special counts for predators only are made, examination of whole plants is more efficient in estimating populations. Population determinations are made using the cloth-sheet method described for cotton fleahopper. Use of sequential sampling will usually reduce the number of sample units needed in making pest management decisions at about a 90 percent level of reliability.

Cotton Pests Outside of the Continental United States

Some major pests of cotton in other countries and Hawaii that do not occur in the continental United States and that might be accidentally introduced into this country at any time are listed in table 6. Cotton farmers, cotton scouts, county agents, entomologists, and others should be alerted to the possibility of these pests becoming introduced into this country and should collect and submit for identification any insect found causing damage to cotton if its identity is in doubt.

Table 6.--Some major cotton pests of other countries and Hawaii

Family and species	Common name	Plant parts damaged	Distribution
Cicadellidae:			
Empoasca lybica (Bergevin).	Cotton jassid	Foliage	Africa, Spain, Israel.
Curculionidae:			
Amorphoidea lata Motschulsky.	Philippine cotton boll weevil.	Squares, bolls	Philippine Islands.
Anthonomus vestitus Boheman.	Peruvian cotton square weevil.	Similar to that of *A. grandis*	Peru, Ecuador.
Eutinobothrus brasiliensis (Hambleton).	Brazilian cotton borer.	Stems, roots	Brazil, Argentina.
Pempherulus affinis (Faust).	Cotton stem weevil.	Stems	Southeastern Europe, Philippine Islands.
Gelechiidae:			
Pectinophora scutigera Holdaway.	Pinkspotted bollworm.	Bolls	Australia.
Pexicopla malvella (Hbn.).	------	Bolls	Pakistan.
Lygaeidae:			
Oxycarenus hyalinipennis Costa.	Cottonseed bug.	Seed, lint	Africa, Asia, Philippine Islands.
Miridae:			
Horcias nobilellus (Berg).	Cotton plant bug.	Terminals, squares, young bolls.	Brazil, Argentina, Paraguay.
Lygus lucrum Meyer-Dür.	do	do	China.
Taylorilygus vosseleri Poppises.	do	do	Africa.
Noctuidae:			
Diparopsis castanea Hampson.	Red bollworm	Bolls	Africa.
Earias insulana (Boisduval).	Spiny bollworm	Young growth, bolls.	Africa, Asia.
Earias vittella (F.)	Spotted bollworm	Terminals, squares, bolls.	India, Pakistan, Thailand.
Heliothis armigera (Hübner).	Cotton bollworm	Terminals, squares, bolls.	Australia, Africa, Asia, Southern Europe, People's Republic of China.

Table 6.--Some major cotton pests of other countries and Hawaii--Continued

Family and species	Common name	Plant parts damaged	Distribution
Heliothis punctigera (Wallings).	Budworm	Terminals, squares, bolls.	Australia.
Sacadodes pyralis Dyar.	False pink bollworm.	Squares, bolls	Central and South America.
Spodoptera littoralis (Boisduval).	Egyptian cotton leafworm.	Foliage, squares.	Africa.
Spodoptera litura (F.).	Old World cotton leafworm.	Foliage, squares.	Asia, Southern Europe, Hawaii, Pacific Islands.
Olethreutidae:			
Cryptophlebia leucotreta (Meyrick).	False codling moth.	Bolls	Africa.
Pseudococcidae:			
Maconellicoccus hirsutus Green.	Hibiscus mealybug.	Foliage terminals.	Asia, Africa.
Pyralidae:			
Sylepta derogata (F.).	Cotton leaf roller.	Foliage	Africa, Asia, Australia, Pacific Islands.
Pyrrhocoridae:			
Dysdercus peruvianus Guerin.	Peruvian cotton stainer.	Bolls	Brazil, Colombia, Peru, Venezuela.

CONFEREES

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